TO THE READER

KINDLY use this book very carefully. If the book is disfigured or marked or written on while in your possession the book will have to be replaced by a new copy or paid for. In case the book be a volume of set of which single volumes are not available the price of the whole set will be realized.

AMARSINGH COLLEGE

Checked 1976

Library

1905

Class No. 915.02

Book No. T51P

Acc. No. 7991 ✓ Cp.-III

Checked

CHECKED
2009-10

PHYSICAL GEOGRAPHY

PHYSICAL GEOGRAPHY AND GEOLOGY

By L. DUDLEY STAMP, B.A., D.SC., F.R.G.S.

4*s*.

This book is intended to be used as an essential introduction or part of a school certificate course in geography or for the general principles and physical basis of geography courses for the first year of a university.

1914. com. of Econ-of

PHYSICAL GEOGRAPHY

BY

JOHN THORNTON, M.A.

author

NEW EDITION, REVISED BY

L. DUDLEY STAMP

B.A., D.Sc.

WITH MAPS AND ILLUSTRATIONS

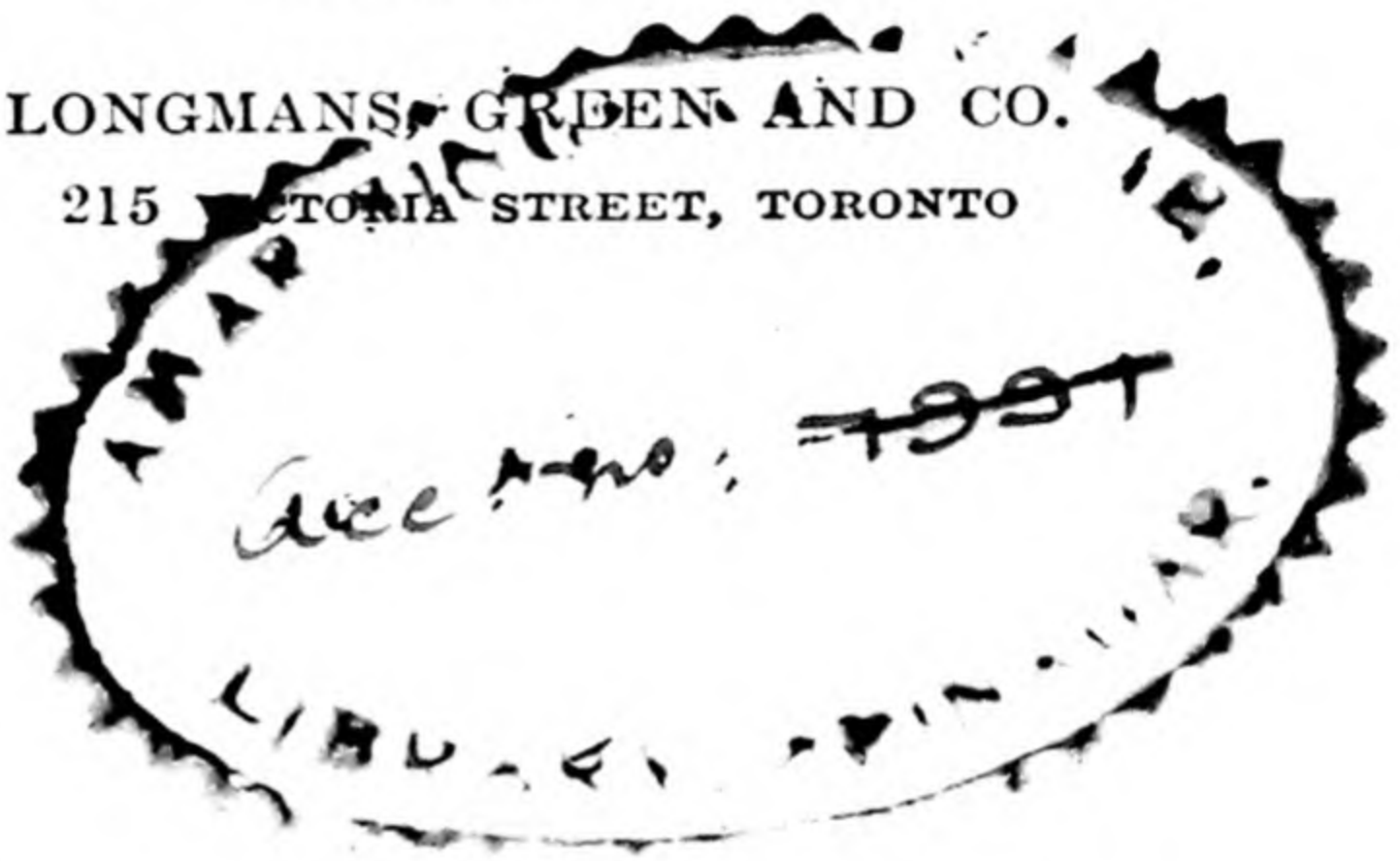
LONGMANS, GREEN AND CO.
LONDON • NEW YORK • TORONTO

2
42 3

LONGMANS, GREEN AND CO. LTD.
39 PATERNOSTER ROW, LONDON, E.C.4
17 CHITTARANJAN AVENUE, CALCUTTA
NICOL ROAD, BOMBAY
36A MOUNT ROAD, MADRAS

LONGMANS, GREEN AND CO.
114 FIFTH AVENUE, NEW YORK
221 EAST 20TH STREET, CHICAGO
88 TREMONT STREET, BOSTON

LONGMANS, GREEN AND CO.
215 VICTORIA STREET, TORONTO



First Edition published in Longmans Geographical Series, 1896.
New Edition revised by Dr. L. Dudley Stamp, published under the title of Physical Geography, November 1936.
Reprinted, November 1939.

910.02
T 394 P

Printed in Great Britain at THE BALLANTYNE PRESS
SPOTTISWOODE, BALLANTYNE & CO. LTD.
Colchester, London & Eton

acc no 7991

EDITOR'S PREFACE

THERE are few tasks which I have approached with greater trepidation than the attempt to prepare a new edition of Thornton's 'Primary Physical Geography.' Yet few have given me greater pleasure, for I am afforded an opportunity of expressing my own indebtedness to the book. It was first published shortly before I was born, and when at the age of twelve for reasons of youthful ill-health I first went seriously to school Thornton became my first, and for two years my only, textbook of geography. I came to know the book almost by heart, and when at the end of the two years I passed first in the country in the Senior College of Preceptors local examination and, as a result, became the proud possessor of a sumptuously bound ten-volume encyclopaedia it is scarcely necessary to add that 'Physical Geography' was one of my seven distinctions. The next year, at the age of fifteen and three months, my brief school career came to a close, but not before Thornton, combined this time with the works of my old friend Lyde, had helped me to achieve a distinction in geography and first-class honours in the Cambridge Senior Local.

I am still young enough to remember those parts of the book which caused me most difficulty and those parts which were supplemented by 'notes' from a wise Headmaster. These sections I have recast and have added elsewhere material which has, in the course of time, become an integral part of the content of the subject. In general, I have endeavoured to preserve as much as possible of a work which can well be described as a school classic.

L. DUDLEY STAMP.

UNIVERSITY OF LONDON,
October, 1936.

ABSTRACT FROM AUTHOR'S PREFACE

In this small treatise on the elements of Physical Geography I have endeavoured to set forth the main facts of this branch of knowledge in a clear and systematic manner. The reasons for most of the statements will be found expressed in simple and concise language, since a reasoned account of natural phenomena has a special educational value for all who study this subject. In preparing the book use has been made of my works on Physiography, while 'Longmans' Gazetteer' has been helpful in several parts. The illustrations have been in part derived from other publications of Messrs. Longman, and in part prepared for this work under my direction.

A special feature of the book is the full Glossary given at the end. This is not only explanatory of technical terms, but is intended to serve as a concise summary, and to be to some extent supplementary to the text. The numerous Questions, partly original and partly taken from published papers, will be found serviceable both as written and oral tests.

J. THORNTON.

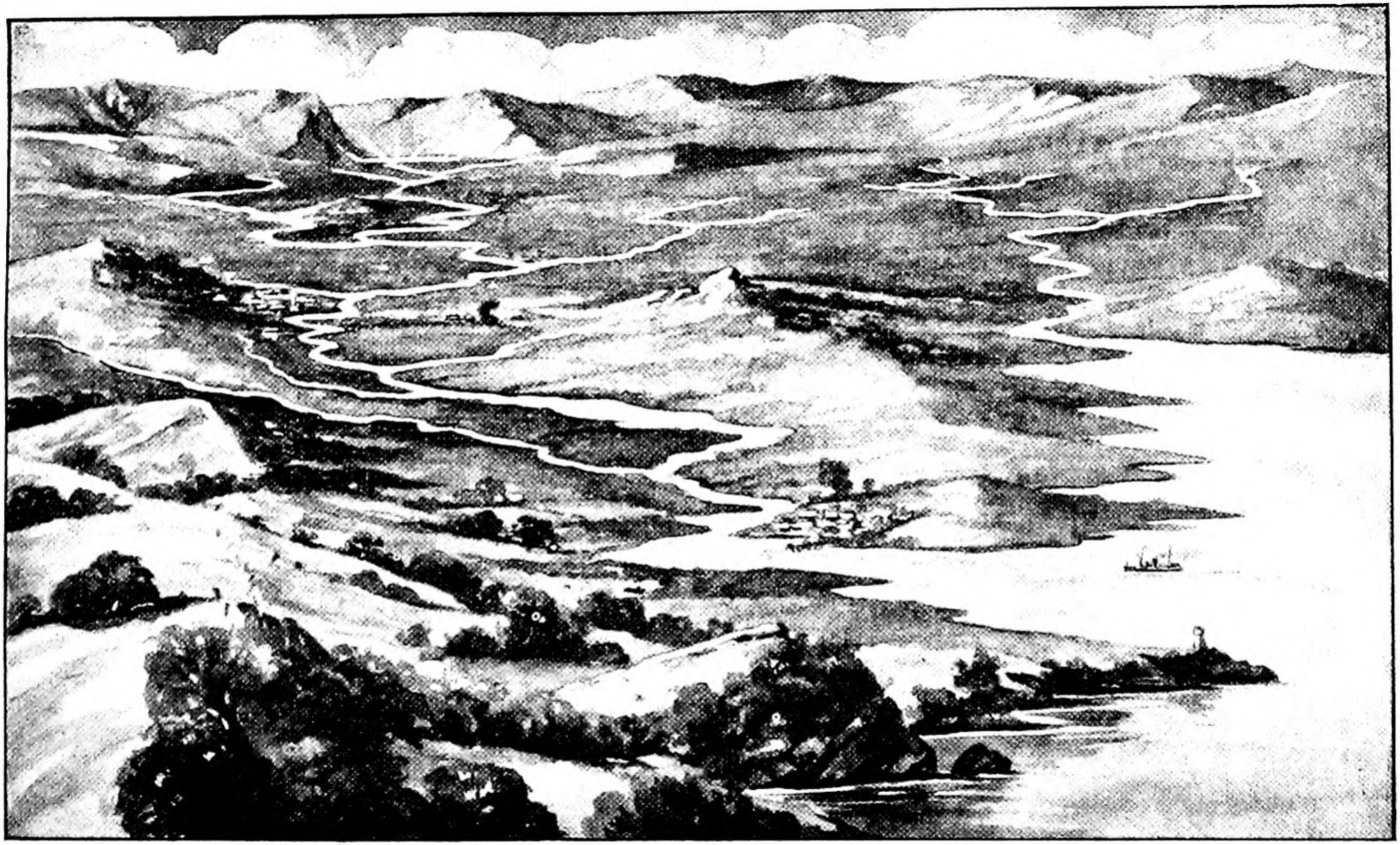
BOLTON,
May 1*st*, 1896.

CONTENTS

CHAPTER		PAGE
	INTRODUCTION	3
I.	THE EARTH: ITS SHAPE, SIZE, AND MOVEMENTS. THE SEASONS	8
II.	THE ATMOSPHERE: ITS COMPOSITION, PRESSURE, AND TEMPERATURE	25
III.	WINDS AND OTHER ATMOSPHERIC PHENOMENA . . .	33
IV.	THE SEA	47
V.	THE LAND	65
VI.	DENUDATION, OR THE SCULPTURE OF THE LAND . .	74
VII.	CLIMATE	85
VIII.	THE GEOGRAPHICAL DISTRIBUTION OF PLANTS AND ANIMALS	101
IX.	MANKIND. TYPES AND RACES OF MAN. INFLUENCE OF NATURE UPON MAN, AND OF MAN UPON NATURE . .	121
X.	MAPS AND MAP-READING	130
XI.	METHODS OF MAP PROJECTION	147
XII.	THE APPARENT MOTIONS OF THE STARS AND OF THE SUN	157
XIII.	THE MOON AND ITS PHASES	170
	GLOSSARY	175
	EXAMINATION QUESTIONS	221
	INDEX	245

LIST OF MAPS

MAP		PAGE
	Coloured Map: Portion of the Land Utilisation Map	*Frontispiece*
1.	The January Isotherms of the Earth	31
2.	The July Isotherms of the Earth	32
3.	Distribution of Mean Annual Rainfall	45
4.	The Currents and Winds of the Atlantic Ocean	57
5.	The Ocean Currents of the Globe	60
6.	Isotherms for the Year	87
7.	Mean Annual Rainfall of British Isles	95
8.	Map showing the Distribution of the three great Types of Mankind	122
9.	Part of a One-inch Ordnance Map, with Contours and Hachures	140
10.	Part of a One-inch Contoured Map, showing the Land around Lake Thirlmere	142
11.	January Isotherms	146
12.	July Isotherms	146
13.	Map showing Active and Recently Extinct Volcanoes	218

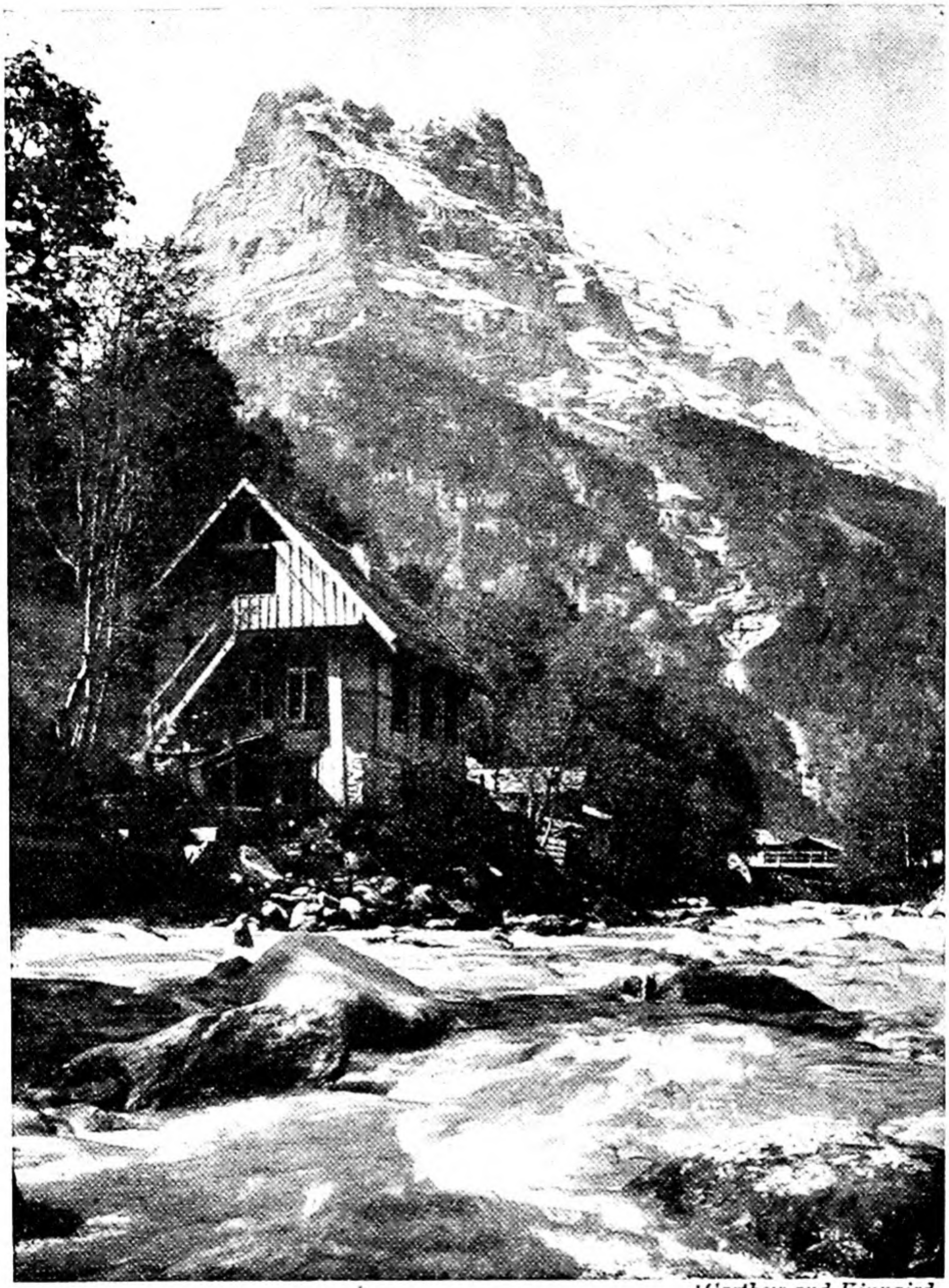


WATERSHED, SHOWING RIVER-COURSES FROM SOURCE TO SEA.

PHYSICAL GEOGRAPHY

INTRODUCTION

IMAGINE yourself with me at sunrise, some fine morning in summer, on the summit of an elevation where you may see a prospect such as that presented in the picture fronting this page. After noticing that the streams all flow in one general direction, owing to the ridge of high land in the background forming a **water-parting,** let us descend the slope and follow the course of one of the streams to the sea. The rough grass and heather of the hill-slope are still wet with **dew,** but, as the sun gets higher, we find this 'dries up.' On the hillside we come to a tiny rill, which seems to be the beginning of our river. Following this on, we find it joined by others, and here and there fed by **springs,** until the volume of water increases so much that it is not easy to cross. In places the bed of the stream makes a sudden descent, so that the water rushes down as a **cascade,** and we notice the huge water-worn blocks of stone in the bed, that must have been carried from above when the stream was stronger. Smooth rounded stones lie on the bank and in the bed, while we see the smaller pebbles and the loose sand pushed along the bottom of the stream until the water reaches a gentler slope. Evidently, in times of flood the stream is fuller and carries along more material, and is then more effective in scouring and deepening its **bed.** As we pass further on we notice that the torrent becomes slower. The stream now takes a rather sudden bend, and its waters, pushing against the concave bank, are clearly wearing it into a deeper bend. Even as we stand a little fall of rock and soil into the stream occurs, and the finer particles are carried on and discolour the water. As the sun has been getting higher and warmer, though there is a gentle breeze, we sit down for rest and refreshment. A cup of water is fetched from the stream, but as it appears rather muddy we allow it to stand, and the **sediment** soon settles to the



[*Carthew and Kinnaird*

FIG. 1.—A MOUNTAIN STREAM.

bottom. Resuming our journey, we notice that on the opposite bank the stream is sluggish and some of the water-borne pebbles and sand form loose **shingle.**

Further down we come to a tributary that increases the volume of our stream, and, passing from the left bank to the

right by a bridge, we then are compelled to take shelter from the **rain.**

The **cloud** soon passes, however, and, a farmer's car coming along, we gladly ride with him on the road that skirts the river's bank. The road is fairly level, for we are now in the lower part of the river valley, where the water runs along quietly, where vegetation is plentiful, and animal life appears on all sides. The farmer tells us of a flood last autumn, when the river overflowed its banks, rushed along in a muddy current, and carried a deposit of mud and silt over the surrounding fields. In the winter a severe **frost** covered over some of the quieter parts with ice, which floated down when the thaw set in.

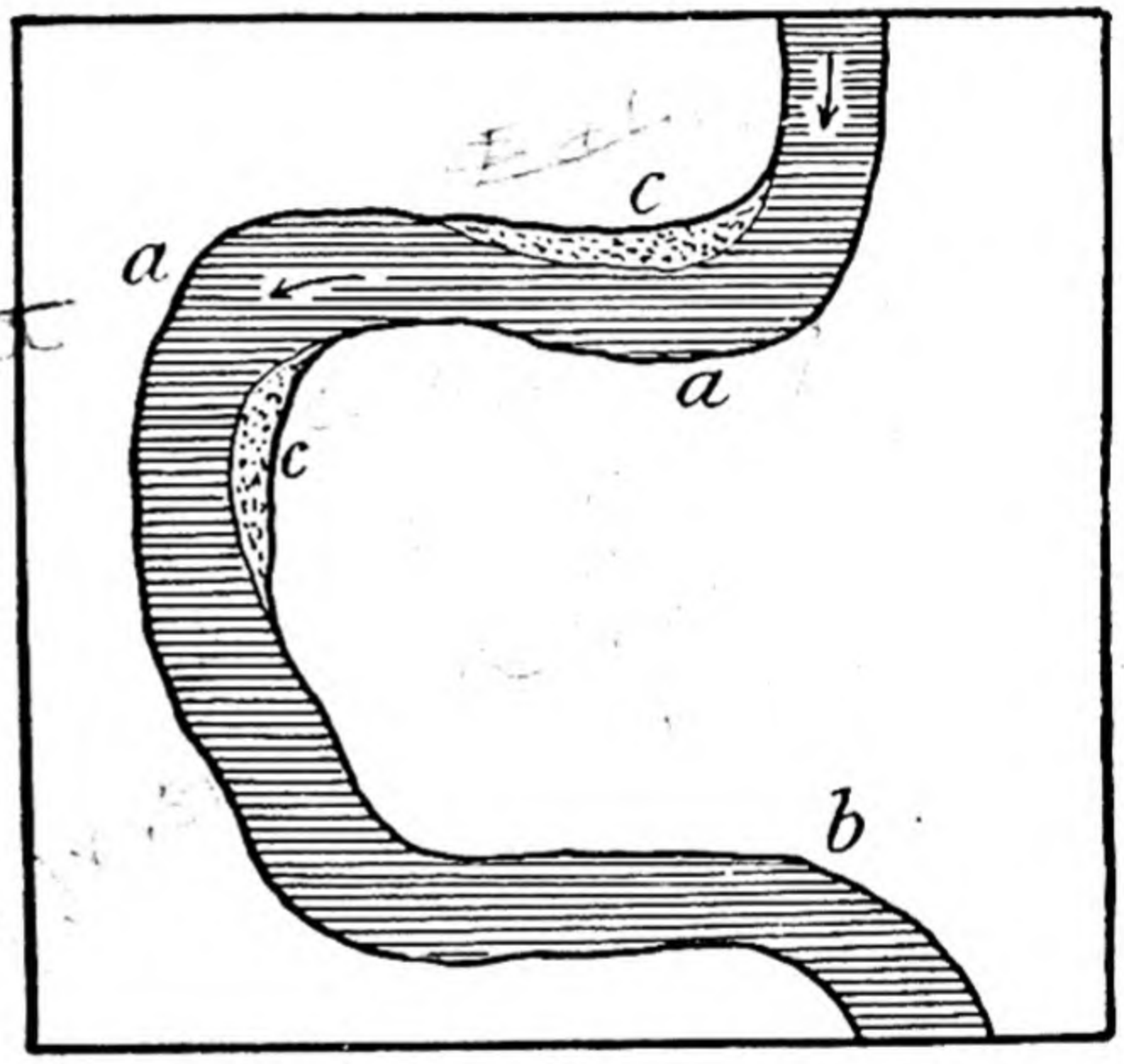


FIG. 2.—DIAGRAM OF WINDING STREAM EATING AWAY THE BANKS AT *a* AND *b*, DEPOSITING SAND AND GRAVEL AT *c*.

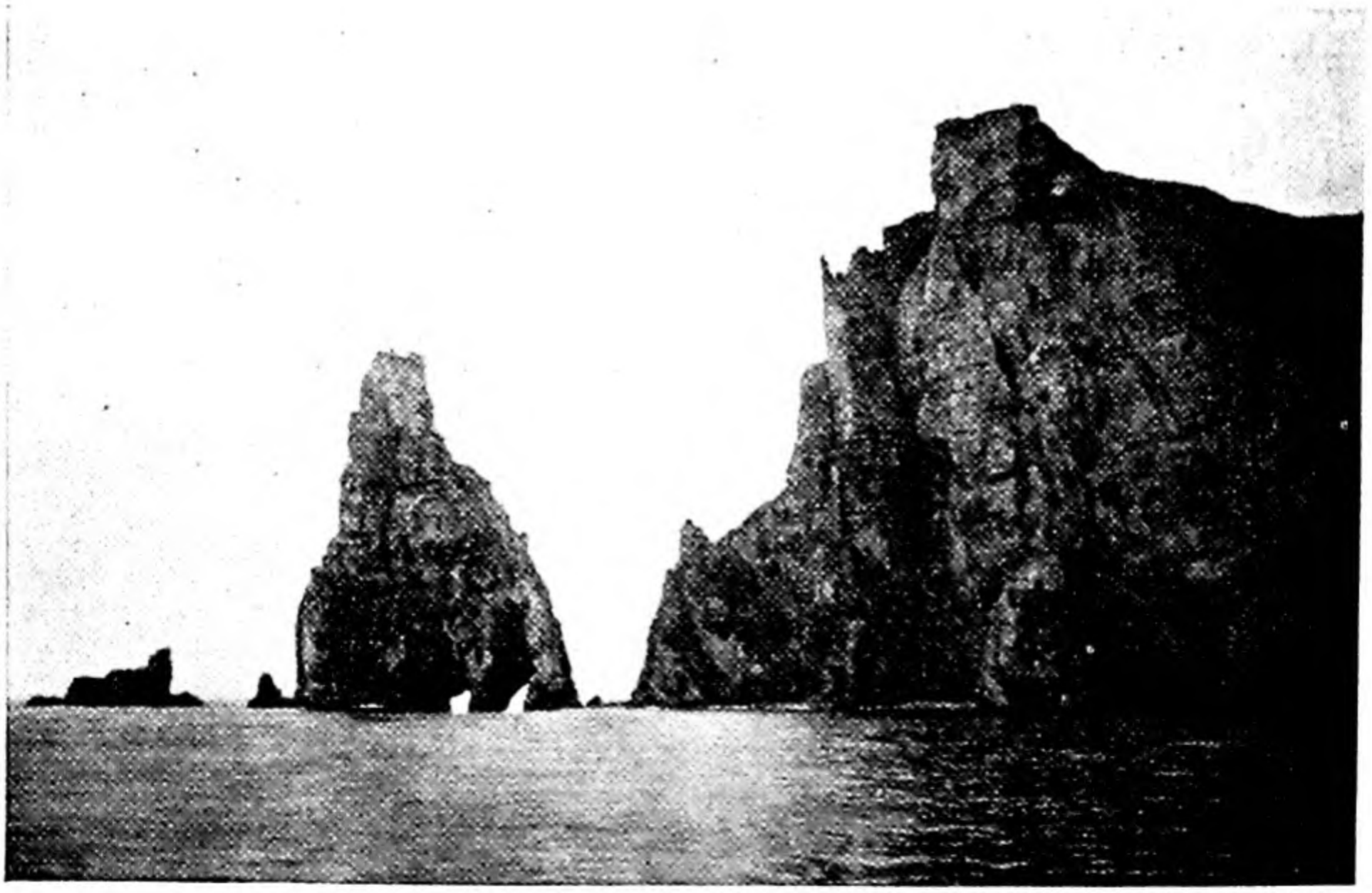
In continuing our journey we notice that the river widens, for we are near its mouth, where it enters the sea. We soon discover that it seems to be getting fuller near its mouth, for the tide is coming in from the sea. From the banks of the **estuary,** or tidal part of the stream, we may observe a ship on the distant **horizon,** the irregular shape of the shore-line, and the rolling **billows** that dash against the rocky headland on which the lighthouse is situated.

Night is fast approaching, and we have just time to return to the little town at the river's mouth when the sun sinks below the western horizon.

What a day of delightful and instructive observations we have had! What a number of questions an inquiring youth may put! Why does the sun rise in one part of the sky, get higher and warmer, and then decline, to set in another part of the sky? Where does dew come from, and where does it go when it disappears? What makes the river flow

[*Photo E.N.A.*

FIG. 3.—A STREAM IN WINTER.



[*Carthew and Kinnaird*

FIG. 4.—STACKS ON A ROCKY COAST. Evidence of waste of coast.

down to the sea? Is it always washing away matter from the land and carrying it down towards lower levels? When does water freeze, and how does frost affect the banks of the stream? Why is the river fuller at some times than at others? Where does the rain come from? What causes the wind, the clouds, and the tide? What produces the rounded pebbles and indented sea-shore, with its caves and stacks of detached rock? Why is the water of the river fresh and the water of the sea salt?

The answer to these and similar questions is furnished by the science of Physical Geography. **Physical Geography** (Greek *phusis*, nature; *ge*, the earth; *grapho*, I write) is a description and explanation of the natural aspects and conditions of the earth. It involves an account of the relations of the earth to the sun; an account of the atmosphere that surrounds the earth, with the phenomena that occur in this gaseous envelope; an account of the land and waters that cover its surface; and, lastly, an account of the varieties of climate and of the vegetable and animal life found in different regions.

CHAPTER I

THE EARTH: ITS SHAPE, SIZE, AND MOVEMENTS.

THE SEASONS

1. **Shape and Size of the Earth.**—The earth on which we live has the form of a ball or globe. Its globular or spherical shape has been established by several proofs.

First Proof.—When we are on the sea, or on a plain where our view is not obstructed, the line which bounds our view, which is called the sensible **horizon,** is always and everywhere

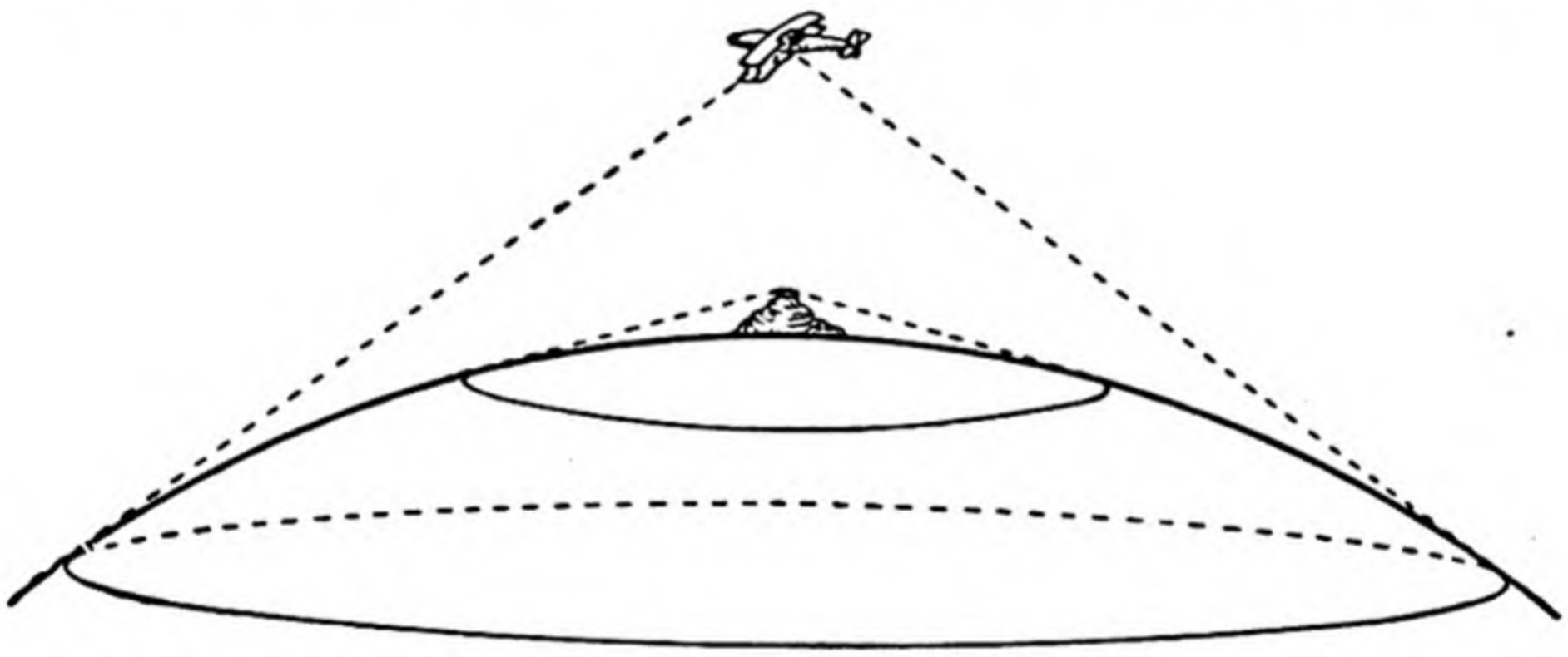


FIG. 5.—CIRCULAR HORIZON INCREASING WITH ALTITUDE ABOVE THE SURFACE.

circular in form, and the higher we ascend the greater becomes the extent of our circular horizon. These appearances can only belong to a body having a spherical form.

Second Proof.—When we first sight a ship on the distant horizon the tops of the masts alone are visible, for the convex surface of the sea conceals from sight the bigger hull. Gradually more and more of the ship becomes visible, until the whole is seen; or, by ascending from the deck, A, to the top of the mast, C (fig. 6), more of the approaching ship is visible. Were the earth flat, as was once believed, the whole ship would become visible at once, or the big hull would be seen first.

Third Proof.—Travellers by sea or land can go quite round the earth in every direction, except where they meet some impassable obstacle, and in circumnavigating the globe no edges or sudden turnings have been met with, such as one would meet on a round disc like a penny,

or on a cylinder like a round ruler. **Fourth Proof.**—The earth in its revolution round the sun sometimes comes between the sun and the moon. It then casts a shadow on the moon, so as to eclipse it, and as this shadow is always circular the shape of the earth must be spherical. **Fifth Proof.**—The daily apparent motion of the stars, and other heavenly bodies, as seen at different distances from the equator, in circles of

FIG. 6.—ILLUSTRATING THE CURVED SURFACE OF THE EARTH.
Curvature much exaggerated.

varying size, whose planes are at right angles to the line joining the north and south pole of the heavens, can only be satisfactorily explained by considering the observers to be on a spherical earth which revolves on its axis every twenty-four hours, thus causing the celestial sphere to appear to revolve in the opposite direction. (*See* Glossary, 'Pole Star,' and fig. 101.)

It may be objected, when we say that the earth is a sphere or great round ball floating in space, that its surface is so uneven owing to high mountains and deep valleys that it cannot be called round. But it must be remembered that these are very small when compared with the great size of the earth. The highest mountain could be represented by a grain of sand $\frac{1}{800}$ of an inch in thickness on a school globe 1 foot in diameter, and the deepest valley would be represented by a slight scratch on the surface of this globe.

Again, it may be asked, Why do not the people who live on the opposite side of the round globe fall off? This arises from a confused idea of **up** and **down.** **Up** is any direction from the centre of the earth, and **down** is any direction towards the centre, and, in whatever part of the world people may live, they have the earth beneath their feet and the blue sky overhead. All people, as well as other objects, are kept on the surface of the earth by a force which draws everything towards the centre of the earth. This attractive force is called **terrestrial gravitation** (*see* Glossary). A stone thrown upwards in England, South Africa, Australia, or in any other part of the world, is brought down again by the attraction of gravitation.

Sixth Proof.—By arranging three posts, A, B, C (fig. 7), at equal heights above the level surface of a sheet of water, as was done in the Bedford Level experiment, it is found that on looking through a telescope so as to just see the tops of A and C, the top of the middle post is above the line of sight.

The rise of a great plain like the level sea between two observers, or

the depression of the surface of the sea from any point, is 8 inches in 1 mile, 8×2^2 in 2 miles, 8×3^2 in 3 miles, and so on for a great distance—*i.e.* the depression is equal to 8 inches multiplied by the square of the number of miles. A tall man, with his eye 6 feet above the

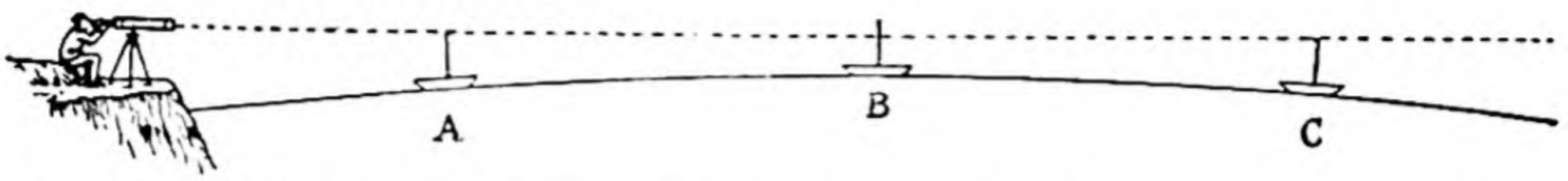


FIG. 7.—SHOWING HOW THE ROUNDNESS OF THE EARTH CAN BE PROVED BY MEANS OF THREE POSTS ON A LARGE SHEET OF WATER.

ground, has thus a visible horizon 3 miles distant (for $8 \times 3^2 = 72$ inches); at a height of 600 feet his horizon would be 30 miles distant. This can only happen on a globe of a certain size.

The earth, then, has a spherical shape. By measuring the amount of curvature of portions of the surface, as well as by measurements of a degree on a meridian, its **size** has been found, and the whole circumference of the globe is roughly 24,850 miles. Its diameter is, therefore, 24,850 miles divided by $3\frac{1}{7}$, or about 8,000 miles. Very accurate measurements, however, show that the earth is not a perfect sphere, for a slight flattening is found at the poles and a slight bulging at the equator. Hence the equatorial diameter is about 27 miles longer than the polar diameter, the polar diameter being exactly 7,899·6 miles, and the equatorial diameter 7,926·6 miles. A sphere flattened at its poles is called an **oblate spheroid** (*see* Par. 11).

2. **Rotation of the Earth on an Axis.—Day and Night.**—The earth turns round on an axis once each day, causing the phenomena of day and night, that half of the globe that is turned towards the sun having day, and the half turned away from the sun having night. A part of the earth just turning towards the sun has 'sunrise'; when directly opposite the sun it is 'noon,' and the sun is highest for that day; when the part is turning away from the sun it is 'sunset.' Its rotation is the only satisfactory way of explaining the daily motions of the heavenly bodies as seen at different places on its surface. Besides, its rotation can be directly proved by causing a pendulum to swing for a considerable time. Such a pendulum keeps its direction in space unchanged, but it is noticed that it changes its path over the floor or table above which it swings, twisting round in the direction of the hands of a watch in the northern hemisphere, and this change must therefore be due to the rotation of the earth and the objects upon it beneath the pendulum. Moreover, this experiment

proves that the earth rotates from west to east, thus causing the daily apparent motion of the sun and other heavenly bodies in the opposite direction. The easterly direction of the trade winds is also evidence of the earth's rotation from west to east.

3. **Terrestrial Latitude and Longitude.**—To indicate the position of any one spot on the earth we imagine circles drawn over it, and draw corresponding circles on a globe which represents the earth. The **axis** of the earth is the imaginary line about which we shall find that the earth spins or rotates. The points where this axis cuts the surface are

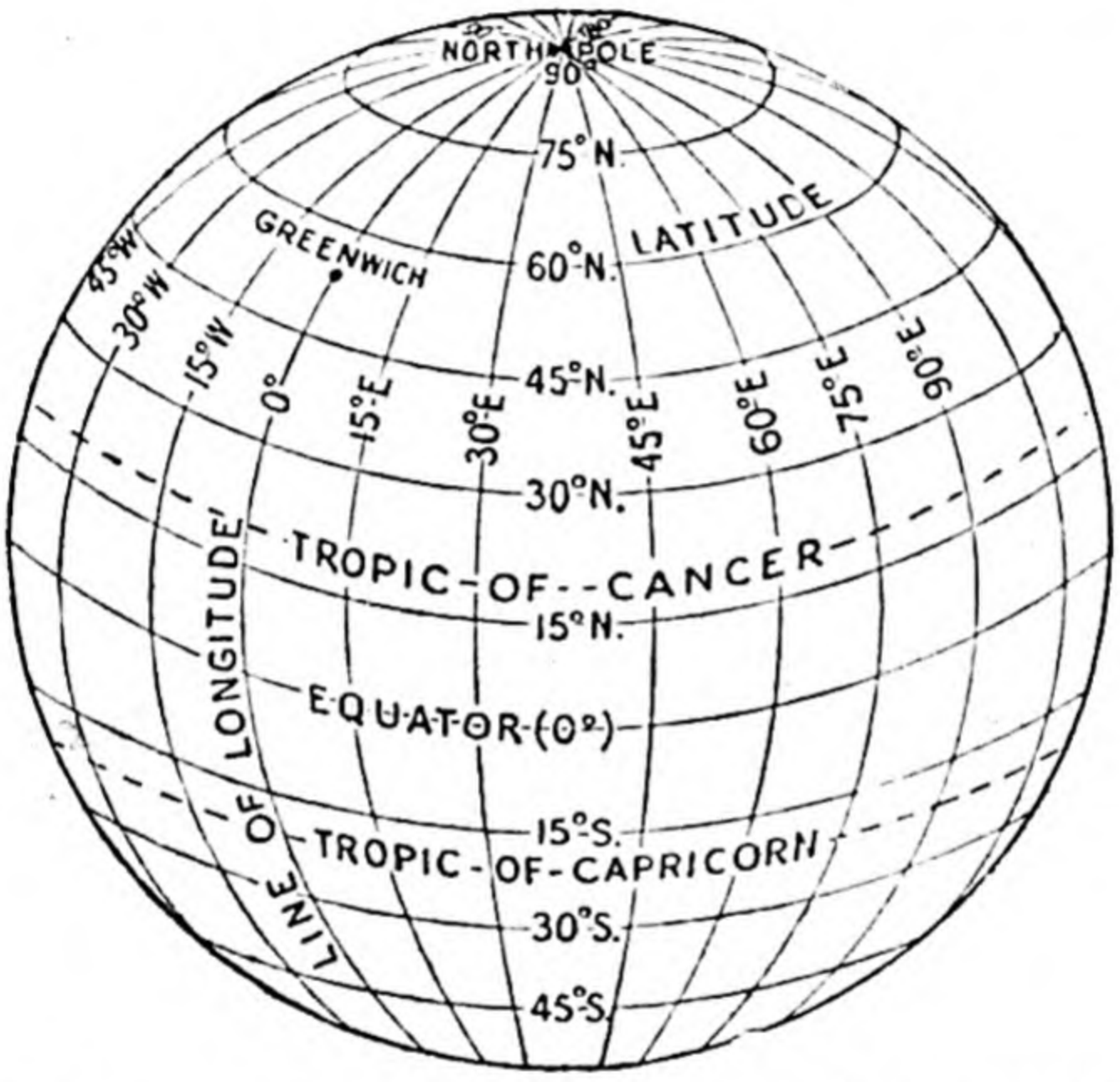


FIG. 8.—LINES OF LATITUDE AND LONGITUDE.

called the **north** and **south poles.** All places equally distant from the two poles are on a **great circle** (*see* Glossary, 'Sphere') called the **equator.** Smaller circles drawn on the globe parallel to the equator are called **parallels of latitude**; and these are drawn on both sides of the equator, being smaller the nearer they are to the poles. They are drawn at equal intervals, and as on the quadrant of a circle from the equator to the pole there are 90 degrees, these circles are marked off in degrees, the equator being 0°, the next circle being called 10° north latitude, or south latitude, as the case may be, the next 20°, and so on, the last circle being really a point at the pole itself 90 degrees from the equator. 'Low latitude' indicates position near the equator; 'high latitude,' position near one of the poles. Of course, we might have more circles than are here indicated, as the intervals might be 1 degree or 5 degrees, instead of 10 degrees. All places on the same parallel circle have the same latitude.

Other circles are drawn, all of the same size, and all passing through

both poles, cutting the equator and all parallels of latitude at right angles. The intervals between these circles are equal at the equator, and are also equal when they cut the parallels of latitude, but the intervals in the latter case are smaller than in the former, as the equatorial circle is larger than any of the other circles of latitude. These new circles are called circles of **longitude,** or **meridians** (L. *meridies*, midday), because when any of these lines is opposite to the sun it is midday or twelve o'clock at all places situated on that meridian on the same side of the globe, and midnight on the opposite side. They are indicated by degrees ; and as there are 360 degrees round the equator, we start from one of the circles of longitude and reckon 180 degrees each way—that is, eastward and westward—till we come to the point opposite to that from which we started.

In England we reckon as the first meridian, or 0°, the circle of longitude which passes through Greenwich, and count the longitude eastward and westward from that starting-point. In other countries other first meridians are sometimes taken, though there is now **an almost general agreement to adopt that of Greenwich.** If, then, we are given the latitude and longitude of a place on the earth, we can easily indicate its position on a sphere.

The degrees of latitude as seen on many maps are drawn at equal intervals, though this is not absolutely correct, owing to the slight flattening at the poles. Hence a degree of **latitude** may be taken as equal to about 69 miles ; for 24,858 miles (the mean circumference) divided by 360 is equal to 69 nearly. The lines of longitude, however, vary in their distance from one another, approaching towards the poles, where they meet in a point. Hence a degree of **longitude** is about 69 miles at the equator only, its length becoming less and less as we get nearer the poles. Thus, at London, 51½° N. lat., a degree of longitude is only equal to about 43 miles.

We have said that the phenomena of day and night are the result of the rotation of the earth on its axis. It will thus be plain that places not in the same longitude will not have their noon at the same time, while on any meridian circle it will be **midday** on the half of the circle turned to the sun, and **midnight** on the other half. The earth turns completely round, *i.e.* through 360 degrees, in 24 hours, and therefore through 15 degrees in 1 hour, or through 1 degree in 4 minutes. Hence a place 10 degrees east of Greenwich has its noon 40 minutes before Greenwich, while at a place 10 degrees west of Greenwich it is 11.20 A.M. when it is noon at Greenwich. On going to New York we seem to gain 4 hours 56 minutes, as it is 74 degrees west ; on going eastwards we seem to lose time. The pupil will thus see how to find the time of the day at any place in the world—'local time,' as it is called—corresponding to any particular time at another place, having given the longitude of the two places. It is also worthy of note that as the mean circumference of the earth is 24,858 miles, and as it rotates on its axis once in every 24 hours, every place on the equator must be carried round at a rate of more than a thousand miles an hour. As we remove from the equator the circles of latitude become smaller, and their rate of motion proportionately less. Thus, at the 60th parallel the rate is only 500 miles an hour, while at the poles the motion ceases altogether. (*See* Questions 3, 160.)

4. **The Zones of the Earth.**—Certain parallels of latitude divide the earth's surface into five natural belts, or divisions,

termed **zones.** As will shortly be explained, the position of these dividing parallels of latitude is fixed by the apparent yearly movements of the sun north and south of the celestial equator along the ecliptic. The part of the earth between the parallels of 23½° north and south of the equator (more exactly 23° 27′) is called the Torrid Zone, or the Tropics, and the bounding parallels are the Tropic of Cancer on the north side, and the Tropic of Capricorn on the south side. The parallel of 66½° north latitude is called the Arctic Circle. The belt of land round the earth between the Tropic of Cancer and the Arctic Circle is called the North Temperate Zone. The parallel of 66½° south latitude is called the Antarctic Circle, and the belt of land between it and the Tropic of Capricorn is the South Temperate Zone. The regions round the two poles bounded by the Arctic and Antarctic Circles respectively are called the Frigid Zones (*see* fig. 144).

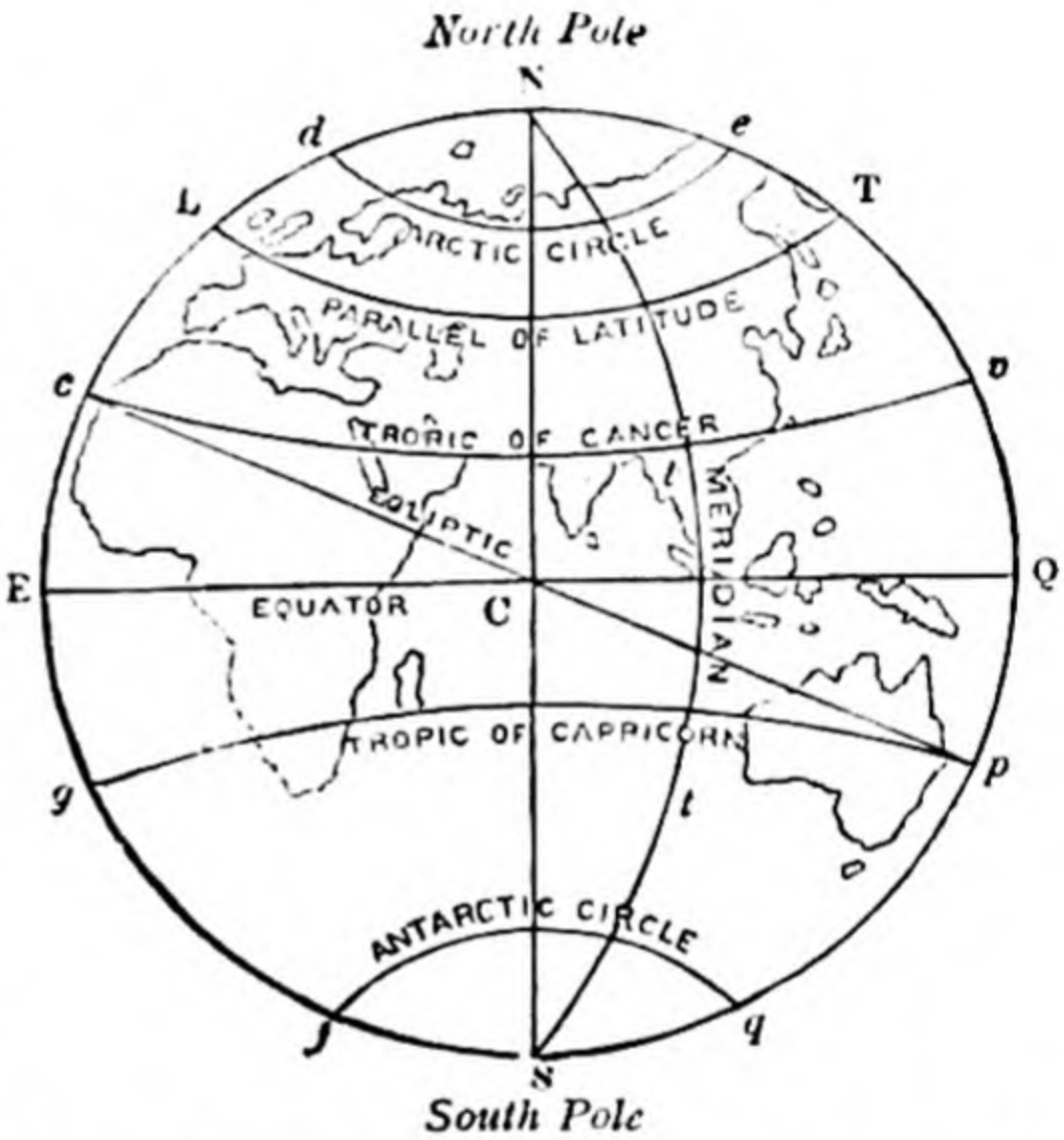


FIG. 9.—ILLUSTRATING THE ZONES INTO WHICH THE EARTH IS DIVIDED.

5. **Annual Revolution of the Earth round the Sun.**—Certain phenomena, such as the changes in the position of the sun with reference to the fixed stars, and the aberration of light, lead us to conclude that the earth revolves round the sun. It performs this revolution in about 365¼ days, and gives us the period called a **year.** The path it follows in revolving round the sun is called its **orbit.** This orbit is in one level or plane, and it is found to be not a perfect circle, but an **ellipse,** with the sun in one focus. That our earth is nearer the sun in one part of its orbit than in another is shown by observing that the sun **appears** a little larger to us in January than in July. The average or mean distance of the sun from the earth is about 92,500,000 miles.

As the sun is the great source of light and heat on the earth, it appears at first sight that the earth as a whole will receive a much greater amount of heat at one part of its orbit

than at another. But this is not so, for its speed in its orbit varies, being greatest when nearest the sun and least when most distant, and thus the earth as a whole receives equal amounts of heat from the sun in passing over equal angular portions of its orbit. We must therefore remember—

(1) That the earth's orbit round the sun is in one plane.

(2) That the earth's orbit is an ellipse of small eccentricity, with the sun in one focus.

(3) That the earth's velocity in its orbit is not constant, but varies.

In consequence of the earth's yearly motion round the sun the sun appears to have, besides its apparent daily motion from east to west, a slower yearly motion eastwards round the heavens in a great circle called the **ecliptic** (*see* Glossary). The **plane of the ecliptic** is the plane passing through this great circle of the heavens, or (which is the same thing) the plane in which the earth's orbit lies, and it meets the plane of the earth's equator, which is at right angles to the earth's axis, at an angle of $23\frac{1}{2}°$.

It may be noted here that the earth is only one of several bodies, called **planets,** which revolve round the sun, and form with it the **solar system** (*see* Glossary).

6. **Inclination of the Earth's Axis.—Varying Length of Day and Night.—Seasons.**—The revolution of the earth round

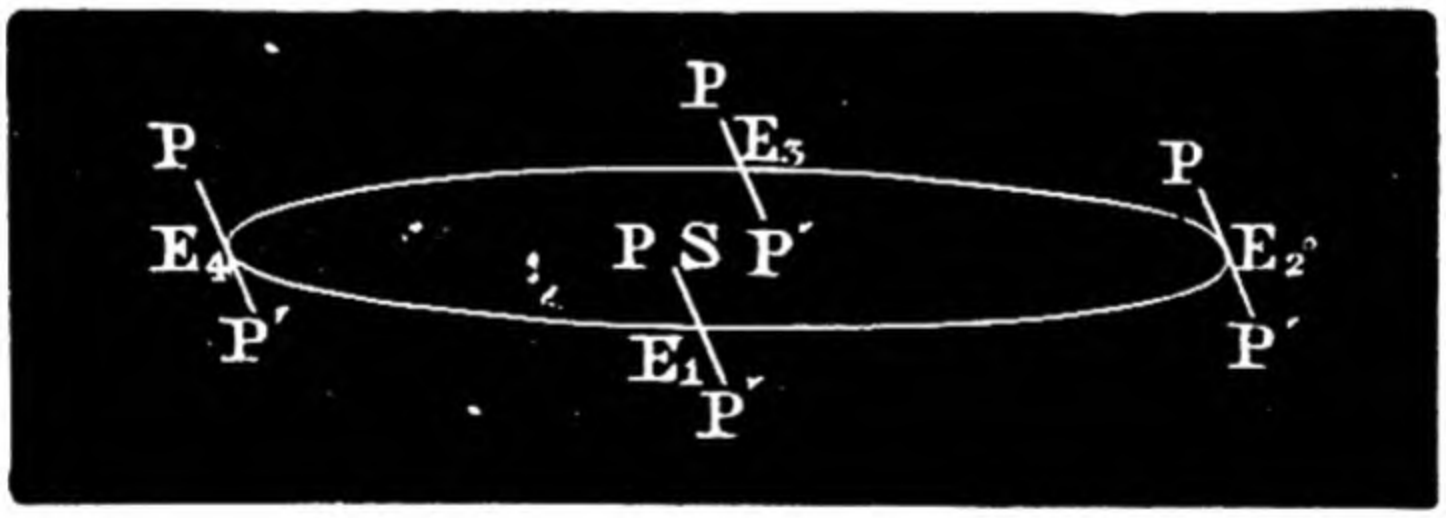


FIG. 10.—SHOWING HOW THE EARTH'S AXIS KEEPS ITS DIRECTION UNCHANGED WHILE THE EARTH CIRCLES ROUND THE SUN.

the sun does not of itself explain the varying length of day and night and the phenomena of the seasons. To do this we must take account also of the varying position of the earth with regard to the sun in consequence of the inclination of its axis to the plane of its orbit. During the earth's annual revolution round the sun its axis remains constantly parallel, 'for the mechanical reason that a spinning body maintains the direction of its axis invariable unless disturbed by extraneous force.' This is also evident from the fact that the

earth's axis always points in the same direction, viz. to the celestial poles, and only parallel lines seem to meet at the same point at a vast distance. The amount of inclination of the earth's axis from the perpendicular to the plane of its orbit is about $23\frac{1}{2}°$. In other words, the earth's axis forms an angle of $66\frac{1}{2}°$ ($90° - 23\frac{1}{2}°$) with the plane of its orbit, or with the plane of the **ecliptic,** as this plane extended to the heavens is

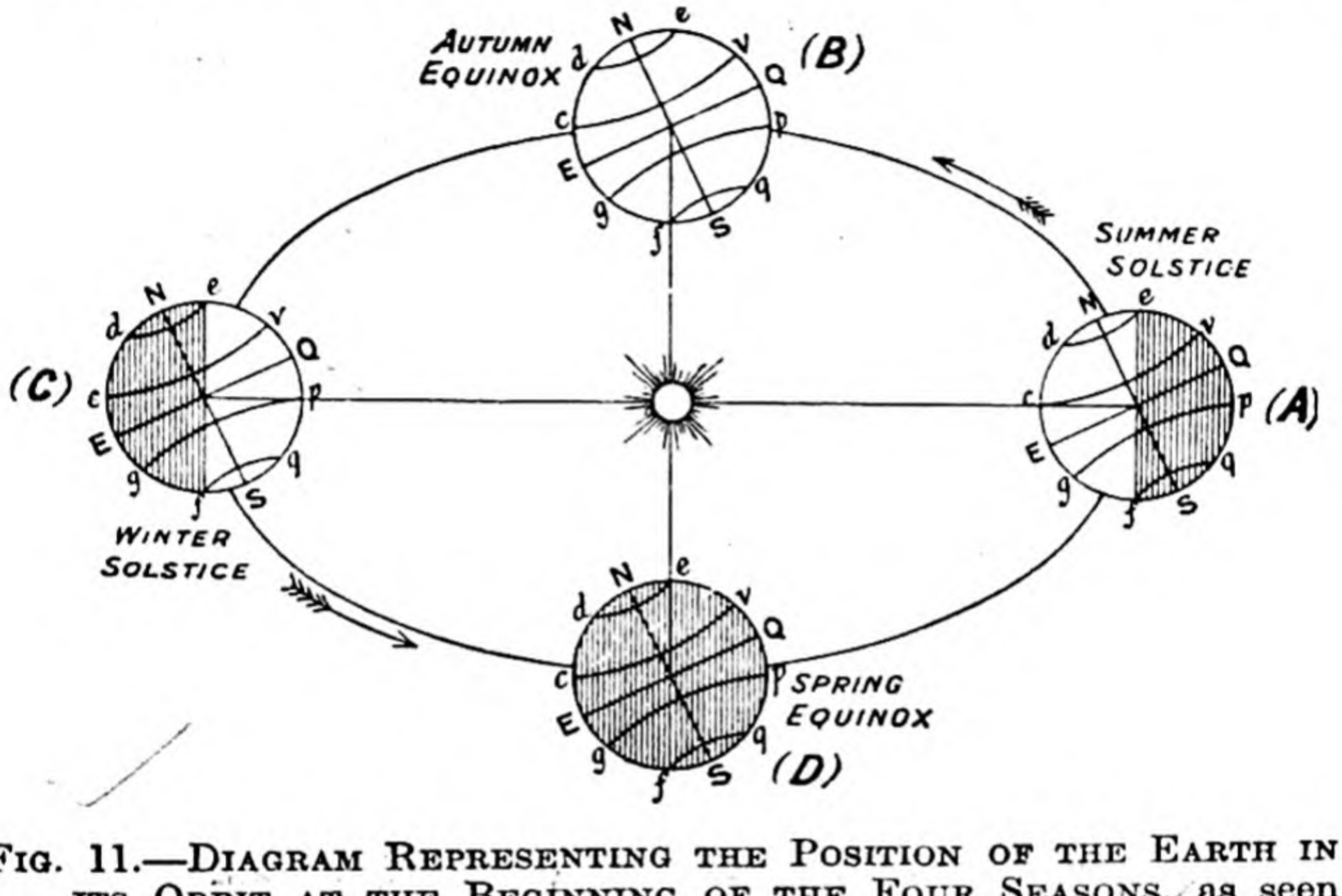


FIG. 11.—DIAGRAM REPRESENTING THE POSITION OF THE EARTH IN ITS ORBIT AT THE BEGINNING OF THE FOUR SEASONS, as seen from one side a little above the plane of the orbit. Only the illuminated half is seen at the autumnal equinox, and only the dark side at the spring equinox. Line *d e* indicates Arctic Circle; *f q*, the Antarctic Circle; *c v*, the Tropic of Cancer; *g p*, the Tropic of Capricorn; *E Q* indicates the equator; *A*, Summer Solstice; *B*, Autumn Equinox; *C*, Winter Solstice; *D*, Spring Equinox. The change from one state of affairs to another is gradual, and it is easy to see why the seasons north of the equator and those south of the equator are at opposite times.

also called. Hence, at certain parts of its orbit round the sun one end of the axis is so disposed that it leans towards the sun, and in the opposite part of the orbit the same end leans away from the sun. At two positions of the orbit the axis is presented exactly sidewise to the sun, so that neither pole then inclines towards or from the sun. These facts are illustrated in fig. 11, which shows the earth in four positions in its orbit, and the pupil must learn to produce this, keeping the axis always parallel to itself and at the proper angle of inclination. (If the earth's axis had been perpendicular to

the plane of its orbit, day and night would have been of equal length throughout the year in all parts, so that there would have been no change of season. If the axis were more inclined from the perpendicular it would lead to an extension of the zones on each side of the equator and greater seasonal differences.)

So important is the proper understanding of the variation in the length of day and night at all places north and south of the equator (at the equator day and night are always of twelve hours each, as this parallel is always equally divided by the line of light and darkness), that we will further consider the four chief positions of the earth in its orbit. The orbit is, of course, in the plane of the ecliptic. N S in each case represents the axis of the earth, N being the north pole and S the south pole.

Let us first consider the position where N, the north pole, is towards the sun, and for this purpose we use a separate figure (12). In this figure *e f* represents a plane perpendicular to the line joining the centres

FIG. 12.—NORTHERN SUMMER AND SOUTHERN WINTER.

of the sun and earth. All that part of the earth on the side of *e f* nearer the sun is illuminated and has daylight; all on the further side has darkness and night. A plane perpendicular to the axis is the plane of the equator, E Q. The circle *e d* described on the earth passing through *e*, the extremity of the shadow, is called the **Arctic Circle.** We see that a place within the Arctic Circle never loses sight of the sun (even 'a midnight sun' is seen in the north of the horizon), never entering the shaded half, during a rotation about the axis N S, so long as the earth and the sun are in the positions indicated by the figure. The corresponding circle *f q* in the Southern Hemisphere is such that all places within it never see the sun during a rotation, the conditions being the same. This circle is the **Antarctic Circle.** The circle *c v*, passing through the point *c* directly under the sun, is called the **Tropic of Cancer.** The corresponding circle *g p* in the Southern Hemisphere is the **Tropic of Capricorn.** We have considered the effect of rotation at places included in the Arctic and Antarctic Circles. Between the Arctic Circle and the equator all places will evidently see the sun for more than half a rotation, *i.e.* have a longer day than night, for more than one-half of each parallel of latitude in the Northern Hemisphere is in the light. Between the Antarctic Circle and the equator the reverse will be the case, night being longer than day. The sun will during the course of the day pass overhead to all places on the circle *c v*.

All this, we must remember, is while the earth is in the position when the north pole is most inclined towards the sun.

The next figure (13) shows the earth at the opposite side of the orbit, where the two hemispheres are just reversed in all respects so far as light from the sun is concerned. Thus, within the Arctic Circle there is no sunlight during the rotation round the axis; within the Antarctic Circle the sun is not lost sight of during the rotation, and is seen in the south at midnight. Between the equator and the Arctic Circle

FIG. 13.—NORTHERN WINTER AND SOUTHERN SUMMER.

night is longer than day, and between the equator and the Antarctic Circle day is longer than night.

At either of the intermediate positions the appearances are the same. In these two positions the earth's axis is perpendicular to the line joining the centre of the earth and sun, as we see by a figure (14); and here we see that day and night are of the same length at all parts of the earth. An observer on the sun would see the earth's equator edgewise, and the circle dividing light from darkness passes through the two poles, thus cutting all the parallels of latitude equally. These positions are called the **equinoxes**, because day and night are then of equal length everywhere. The first two positions discussed are called the **solstices.** From solstice to equinox the appearances above described change gradually, and so from the equinox round to the other solstice.

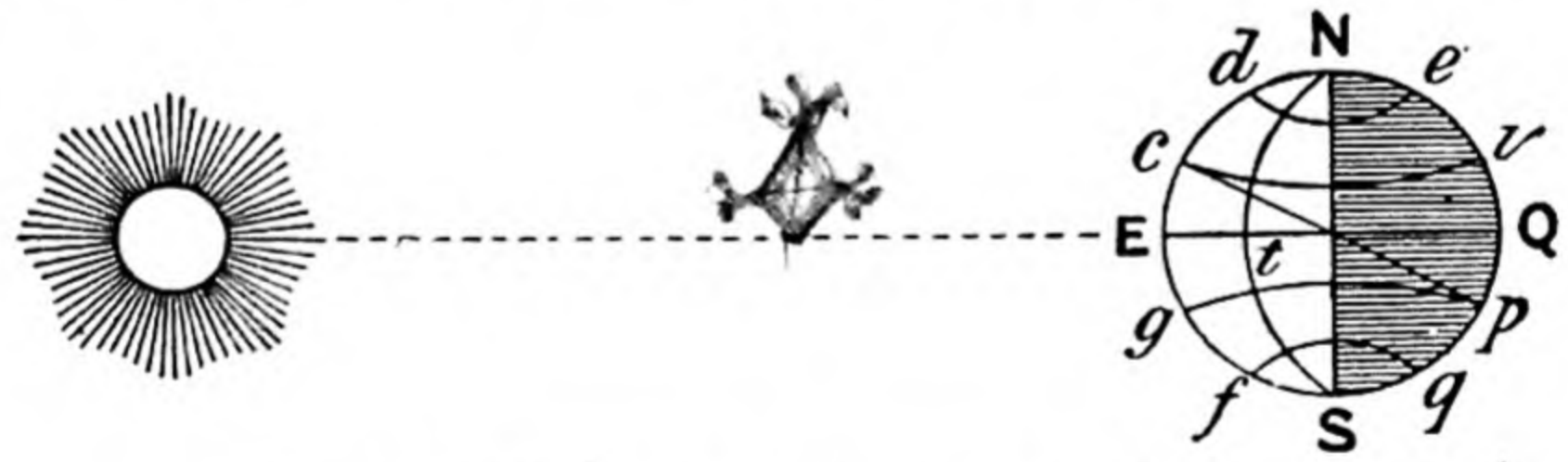


FIG. 14.—VERNAL OR AUTUMNAL EQUINOX.

Thus, in the Northern Hemisphere, at the summer solstice the sun at midday is high in the heavens, and on each succeeding midday gets lower and lower; at the same time the day shortens and the night lengthens till the equinox, when they are equal in length. After the equinox the sun is still lower at midday, and now the nights are longer than the days, and the difference increases till the winter solstice is reached. Then the midday sun is at its lowest in the heavens, and on two successive days seems to occupy the same place—to stand still, as it were, and hence the name **solstice** (*see* Glossary). After this the

changes are all gone through back again till the summer solstice is again reached, and then we say one year is completed.

We notice, further, that all places within the Arctic Circle have at least one day in which the sun never sets, and one in which it never rises. The poles themselves see the sun for six months, and lose it for six months. Within the two tropics every place has the sun overhead, or in the zenith, twice a year, once when moving north and once when moving south. This occurs at intervals of six months at the equator, but at smaller and smaller intervals north and south of the equator, until it occurs at two successive days at the tropics themselves (*see* Glossary, **Tropic**). Between the Tropic of Cancer and the Arctic Circle, and between the Tropic of Capricorn and the Antarctic Circle, we have two zones which have appearances lying between the two last described, for they never have a vertical sun, nor a day in which the sun fails to rise or set.

The following table shows the longest duration of sunlight, *i.e.* the longest day, at different latitudes :—

Latitude.		Latitude.	
0° (Equator)	12h 0m	60°	18h 30m
10°	12h 35m	66° 33′ (Arctic Circle)	24h 0m
20°	13h 13m	70°	2 months
30°	13h 56m	80°	4½ months
40°	14h 51m	90° (Pole)	6 months
50°	16h 9m		

We add a diagram (fig. 15) to illustrate these different lengths of the longest day at every 10 degrees of latitude in the Northern Hemisphere when the north end of the earth's axis is most inclined to the sun. The length of the longest night in winter is the same as that of the longest day in summer.

There is some increase in the duration of daylight beyond the above times due to the illumination of the atmosphere after sunset and before sunrise—**twilight** and **dawn.** This illumination continues until the sun is 18 degrees below the horizon, and is more marked the farther north we advance. (*See* Glossary, 'Twilight.')

7. **Distribution of the Sun's Light and Heat on the Earth.**—That half of the earth's surface which is turned towards the sun receives light and heat from it; the other half is in darkness.

The light, and especially the heat, derived from the sun at any place are greatest when the sun is highest in the heavens, and can therefore send its rays more nearly perpendicular to the ground. There are two reasons for this :—

(1) When the sun is higher the rays from it pass through less of the earth's atmosphere, and so less heat is absorbed by that atmosphere before they reach the ground.

(2) When the sun is higher the number of rays received by any particular piece of ground is greater than when the sun

is lower—*i.e.*, the quantity of heat received by a square yard of ground increases as the sun's altitude increases. This is the main reason for the increased heating power of the more perpendicular rays.

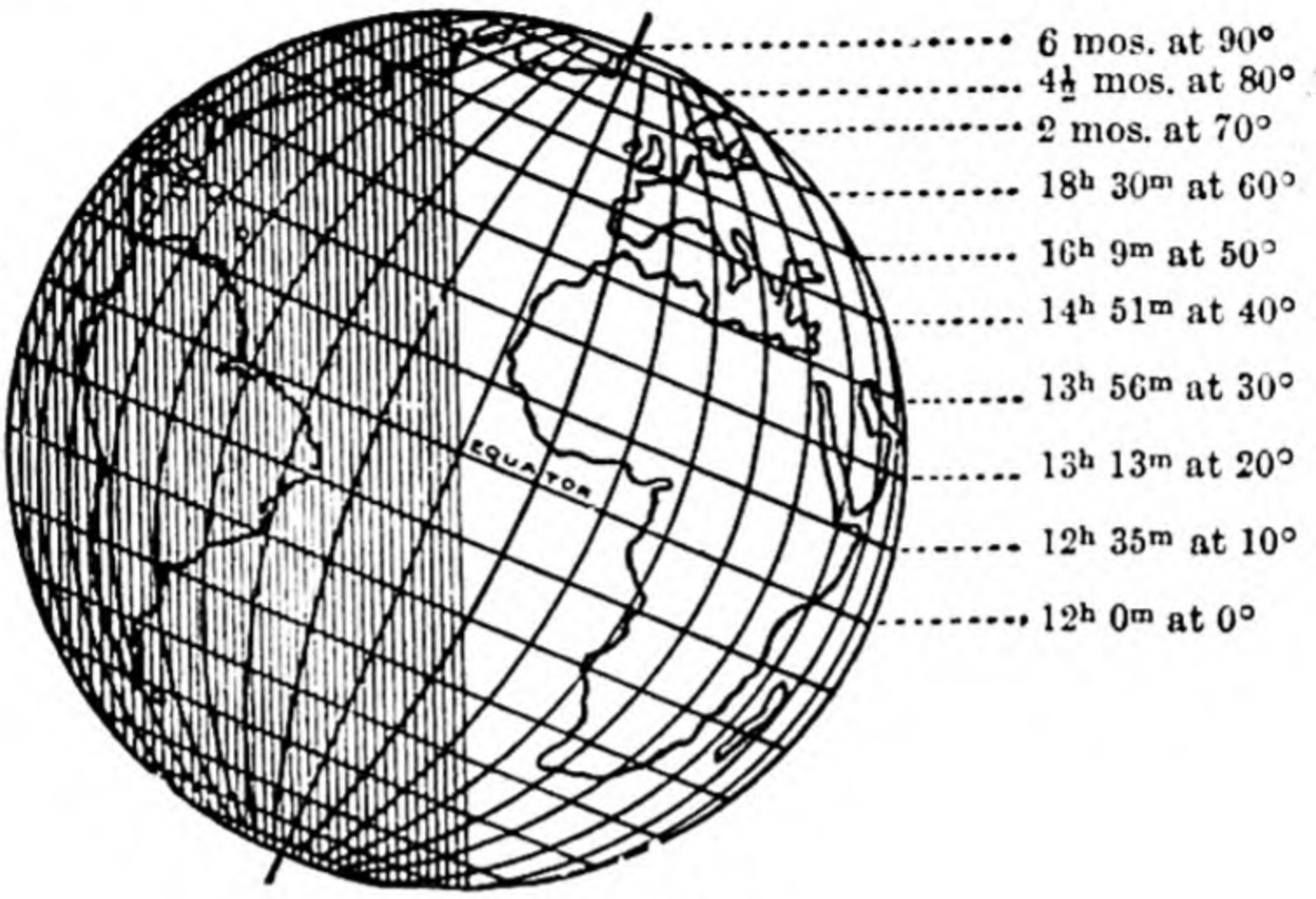


FIG. 15.

By a figure we can illustrate the combined effect of these two causes. A and B, fig. 16, represent equal bands of rays, the former near the pole, and the latter between the tropics. We see that the band A has not only to pass through a greater thickness of atmosphere, but that it is spread over a greater area of ground, *a b*, than the band B, whose rays are concentrated over the much smaller area, *c d*. When the sun's noonday altitude is 60° the amount of heat is one-fourth less than when the sun is vertically overhead; when 50°, one-third less; when 35°, one-half less, and when 25°, nearly three-fourths less. It is thus easy to understand why our summer sun has so much more power than the winter sun. (*See* fig. 25.)

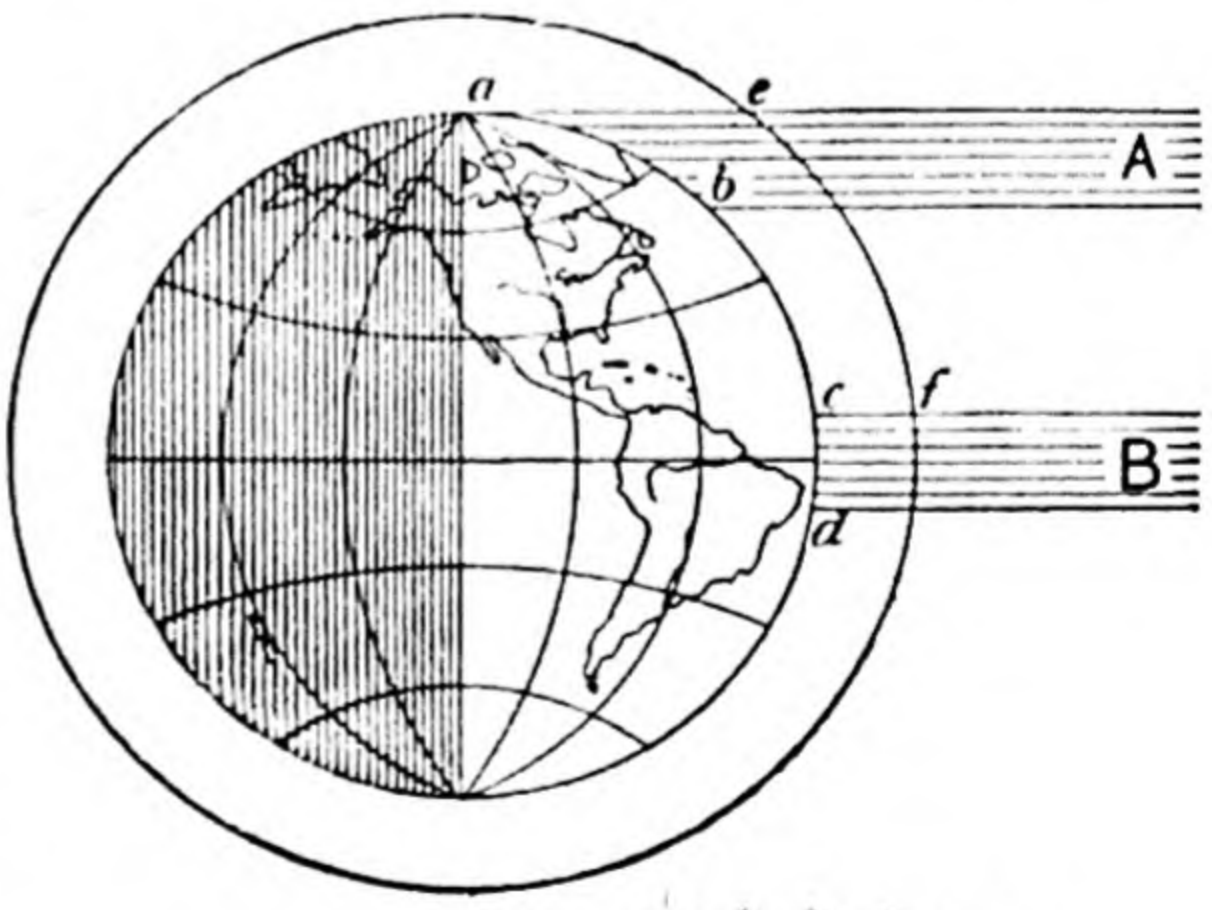


FIG. 16.

SINGH COLLEGE
Acc. No. 7991

There is still another cause that affects the temperature of the various parts of the earth at different periods of the year, for it must be plain that the length of the day, or the time which the sun remains above the horizon, has great influence. While the sun is shining those parts of the globe exposed to his rays are receiving heat. After the sun has set these parts are losing heat, the heat passing away by radiation into space. Hence places are most heated when the days are longest. The more distant a place is from the equator, the greater is the difference between the length of its days and nights, and the greater will be the variation of its temperature during the year. Although we receive most heat in twenty-four hours at the time of the summer solstice, this is not the hottest period of the year. The maximum temperature at any place usually occurs at the end of July, because during most of the summer the heat received from the sun during the day is in excess of that lost by radiation during the night, and so the temperature goes on increasing until the loss by night is just equal to the gain by day. (So the greatest heat of any day is not until about two hours after noon, when the gain and loss each minute are balanced.) In autumn the loss by night begins to be greater than the gain by day. The minimum temperature of the year occurs when the gain by day again becomes equal to the loss by night, and this happens about the end of **January in the Northern Hemisphere.**

A simple way of finding the greatest and least altitude or height of the midday sun at any latitude, and also of showing its equal altitude at the equinoxes, is shown in figs. 17 and 18. A line drawn from the centre of the earth through any particular place passes to the zenith of that place, and a line from the centre of the earth to the sun at noon will then show the angle separating the sun from the zenith, *i.e.*, the zenith distance of the sun at the place of observation. Measure this angle, and by subtracting the zenith from 90° we get the altitude or height above the horizon. The less the zenith distance, the greater will be the altitude. In the figure, L represents London (lat. 51½°) and z indicates the zenith. The figures may be drawn for other latitudes. (*See* also fig. 107.)

Were there no other causes affecting the distribution of the sun's heat on the earth, the temperature would decrease gradually from the equator to the poles, and climate would be determined by latitudes. But height above the sea-level, nearness to the sea, prevailing winds, and ocean currents, have important effects on the temperature of places, as will be seen when we discuss the subject of climate (Chapter vii.).

8. **The Seasons.**—From what has been said it is easy to see that the succession of seasons is due to the annual revolution of the earth round the sun, combined with the constant inclination of the earth's axis, for these lead to the varying height of the sun, on which the heating effect of its rays

depend, and to the greater length of time that it shines during the day in summer compared with the time it shines in winter. The four seasons are most distinctly marked in the temperate regions of the globe, and occur at opposite times of the year in the north and south hemispheres. Within the tropics the inclination of the sun's rays varies so little during the year

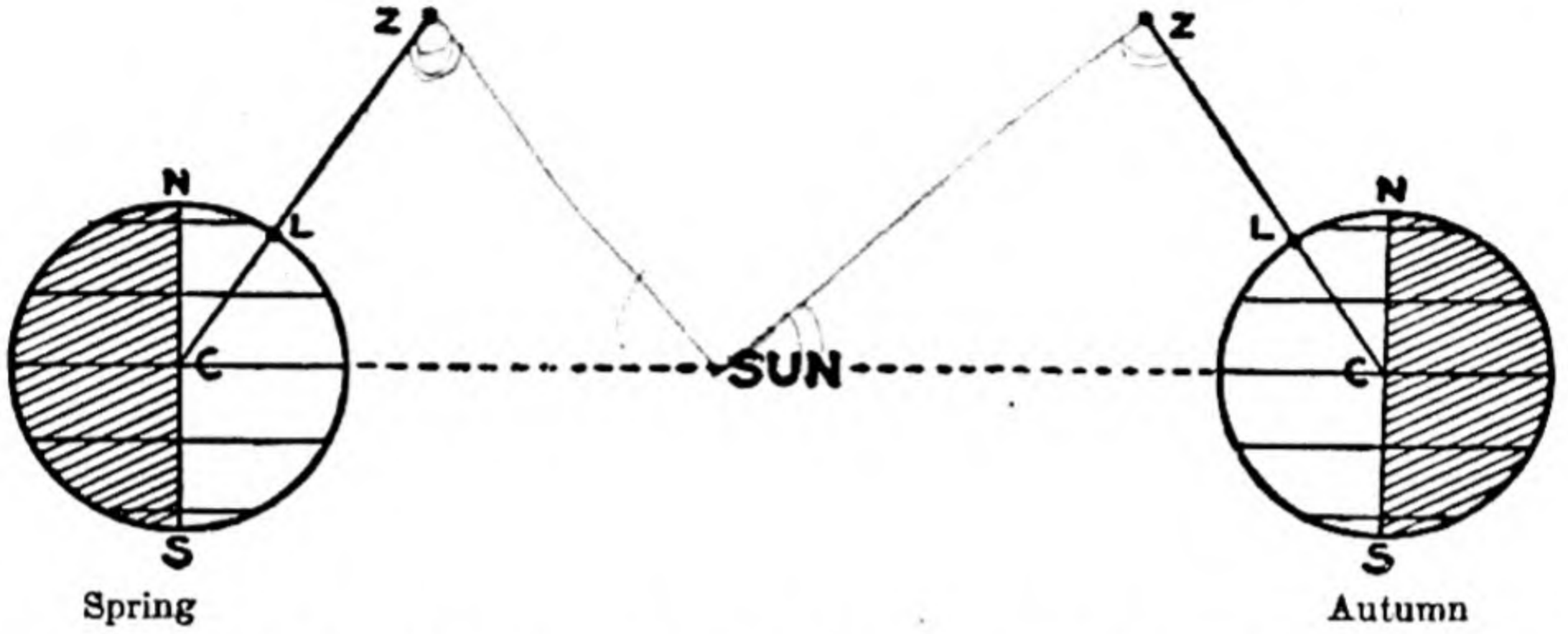


FIG. 17.—DIAGRAM SHOWING THE EQUALITY OF THE SUN'S ZENITH DISTANCE AT THE TWO EQUINOXES. Angle Z C S (sun) = zenith distance.

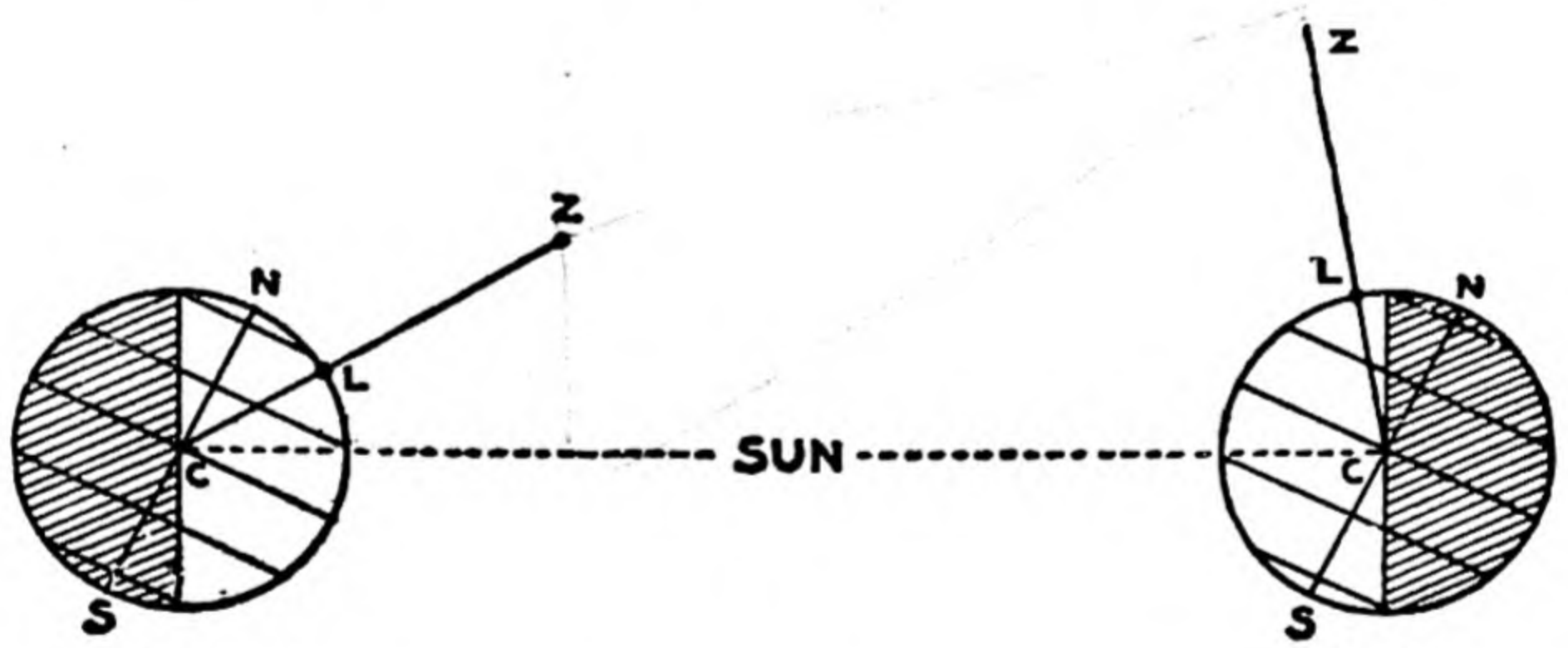


FIG. 18.—DIAGRAM SHOWING THE DIFFERENCE BETWEEN THE SUN'S ZENITH DISTANCE AT THE TWO SOLSTICES AT THE LATITUDE OF LONDON. Angle Z C S subtracted from 90° gives the altitude.

that all parts of the year have nearly the same temperature. In the arctic and antarctic regions spring and autumn are but brief, while there is a long summer and long winter; so that we may say that these districts have but two seasons. According to the almanacs, each season begins with an equinox or solstice.

The Vernal or Spring Equinox is on March 21, and Spring begins.
The Summer Solstice is on June 22, and Summer begins.
The Autumnal Equinox is on September 23, and Autumn begins.
The Winter Solstice is on December 22, and Winter begins.

Finding the intervals between these dates, we shall learn that the seasons are of unequal length. Winter is about $4\frac{1}{2}$ days shorter than summer in our hemisphere. We say 'about,' because to be quite accurate we should give the exact time on the above dates when each season begins, for spring begins at the moment the sun reaches the vernal equinox on March 21; summer, the moment the sun reaches the summer solstice on June 22, and so on. The four seasons are, in fact, the periods into which the year is divided by the equinoxes and solstices. Their lengths at present are, to the fraction of an hour—

Winter.	Autumn.	Spring.	Summer.
89d. $0\frac{1}{2}$h.	89d. $18\frac{1}{2}$h.	92d. $20\frac{3}{4}$h.	93d. $14\frac{1}{2}$h.

Spring and summer together in the northern hemisphere, when the sun is north of the equator, are thus about seven days longer than autumn and winter. The cause of the inequality in the length of the seasons is the varying speed of the earth in its orbit, as it moves through the four quadrants of this orbit in unequal times.

The four seasons of temperate regions are marked by certain phenomena of plant life, such as the budding, blossoming, fruit-bearing, and leafless condition of many trees. Changes in the thickness of the fur or feathers of animals are also found in those regions where the seasonal changes are great. Certain winds, as the monsoons of the Indian Ocean, and certain periodical rains, also depend on the seasons. Indeed, within the Torrid Zone, or Tropics, as the rain falls at the part of the year when the sun is in the zenith, while the rest of the year has hardly any rain, this part of the earth is said to have a **rainy season** and a **dry season** only. India has also a wet season and a dry season—a wet season when the south-west monsoon brings air laden with water-vapour from the Indian Ocean (May to October), and a dry season when the north-east monsoon blows from the north of Asia (November to April). (*See* Par. 21.)

9. **The Sun's Shadow.**—Much may be learnt by carefully observing the shadow of a vertical object cast by the sun. The exact time of noon on any day can be fixed by finding the moment when the sun's shadow of a **gnomon,** or upright rod, is shortest. At this time, too, the shadow runs towards the north,[1] and lies exactly on the **meridian,**

[1] In the Southern Hemisphere read south. (*See* Question 193.)

or north and south line of the place of observation. To assist in fixing this line it is advisable to draw circles round the vertical pillar, and note the time when the shadow just reaches a circle before noon and after noon. The midway moment is noon, and the line bisecting the angle between the two shadows is the meridian. The meridian line produced both ways meets the horizon in the north and south points. When facing south, a line through our position at right angles to the meridian line meets the horizon at the east point on our left, and the west point on our right. We can thus fix the **cardinal points.** (*See also* Glossary.)

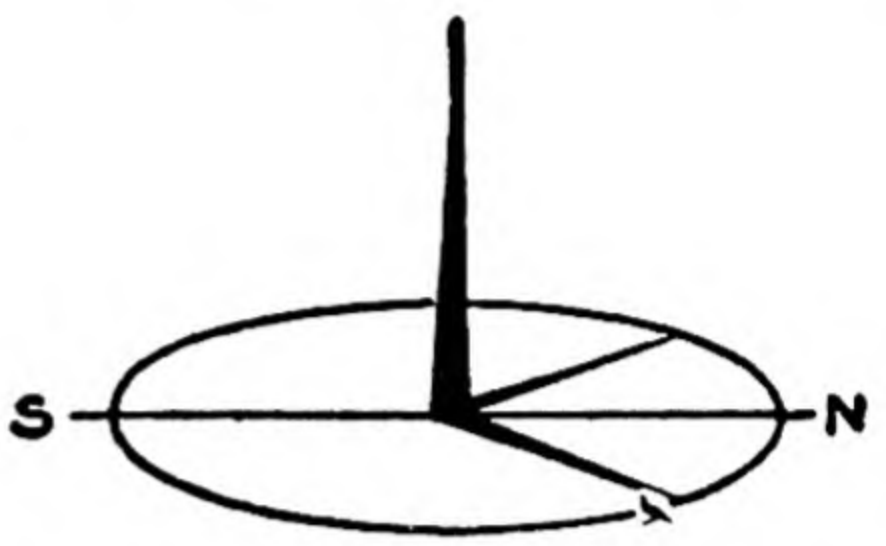


FIG. 19.—METHOD OF FINDING THE MERIDIAN.

Again, by finding on which day of the year the noonday shadow is shortest for the year, we should find the date of the summer solstice, when the sun reaches its highest point in the heavens outside the tropics. In the northern hemisphere the sun is vertical over the Tropic of Cancer at this time, and at this tropic there would be no shadow at noon on that day. The date of the winter solstice could be fixed by finding the day of the year on which the sun is lowest at noon, and therefore throws the longest noonday shadow. The day on which the shadow

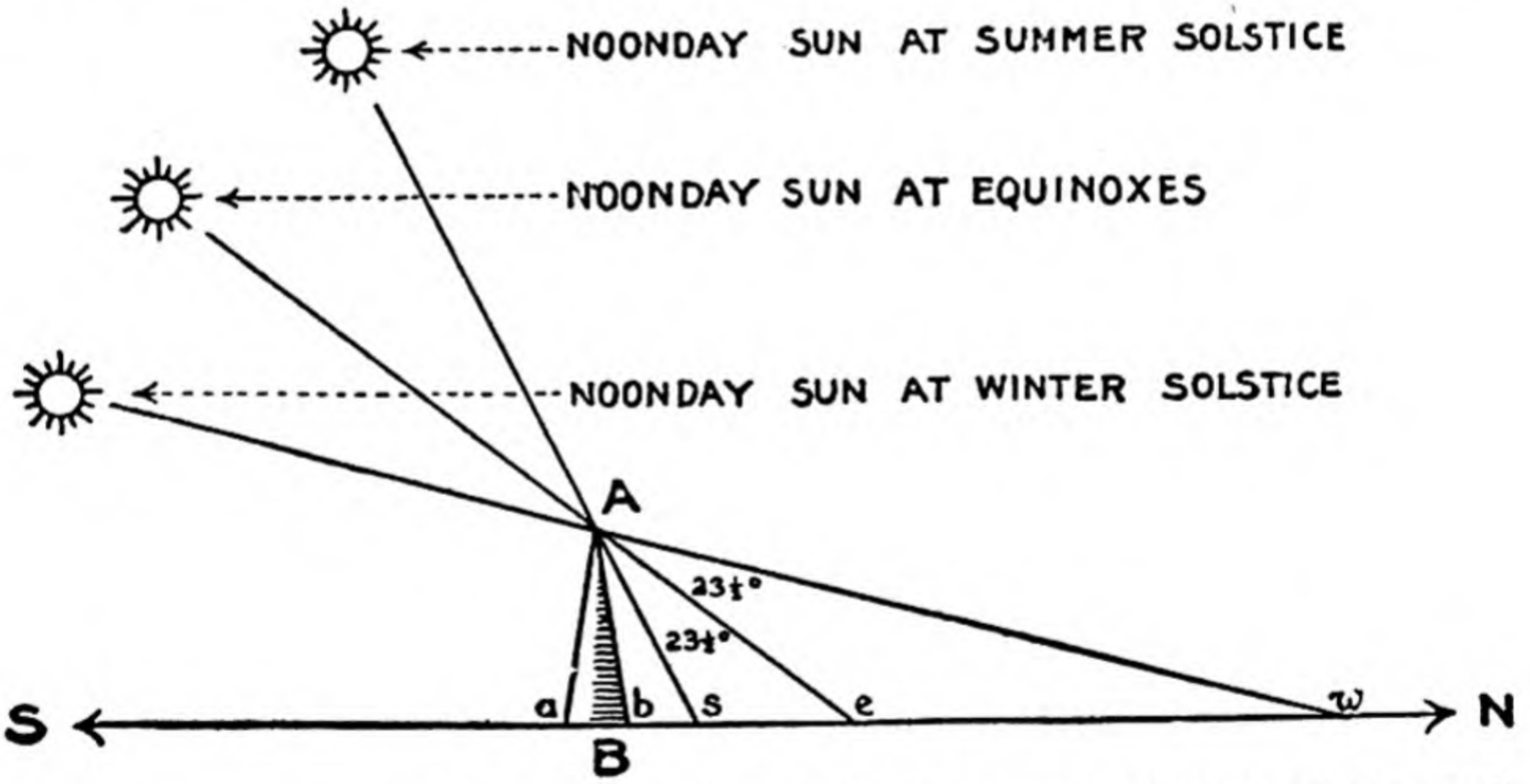


FIG. 20.—ILLUSTRATING HOW THE SUN'S VARYING DECLINATION, THE OBLIQUITY OF THE ECLIPTIC, AND THE DATE OF THE EQUINOXES AND SOLSTICES MAY BE DETERMINED. *b s*, *b e*, and *b w* show the relative lengths of the noonday shadow of the gnomon at the times indicated. (For the Northern Hemisphere.)

of a vertical rod cast by the rising sun is in the same straight line as that cast by the setting sun gives us the date of an equinox, for it is only at the spring and autumnal equinoxes that the sun rises exactly at the east point and sets exactly at the west point. After the spring equinox (March 21) the sun rises more and more north of east, and sets

more and more north of west until the summer solstice. After this date (June 22) the rising point gradually comes back to the east, and the setting point to the west, until after the autumnal equinox (September 23) the sun rises more and more south of east and sets more and more south of west until the winter solstice (December 22). (*See* fig. 105 and Questions 176, 177, 193, 196).

By measuring the time from one summer solstice to the next we could find the length of a year by observation of the shadow.

10. **Summary of the Effects of the Earth's Two Motions.**—The diurnal or daily **rotation** on an axis produces the daily rising and setting of the sun, moon, and stars. By bringing various parts of the earth for a certain time into sunlight, and then carrying each part out of the sunlight, the alternation of light and darkness called **day** and **night** is produced. Rotation also gives us the length of a complete day, a **solar day** being the interval of time between the sun reaching its highest position in the south and its next reappearance on the meridian.

Revolution causes the sun to appear to move eastward amongst the stars, and to trace out the great circle in the heavens termed the **ecliptic,** in the plane of which the earth's real orbit lies.

Revolution, **combined with the fixed inclination of the earth's axis** to the plane of the ecliptic, produces variations in the altitude of the midday sun, with differences in the length of day and night during a revolution. Hence arise variations of temperature during the year, and the succession of the seasons in the two hemispheres north and south of the equator. (Par. 92.)

Revolution also gives us the length of a year.

11. **The Exact Shape of the Earth.**—We have said that the earth is not a perfect **sphere** (*see* Glossary), but an oblate spheroid—*i.e.*, a sphere slightly flattened at the ends of its axis. This is proved in two ways:—

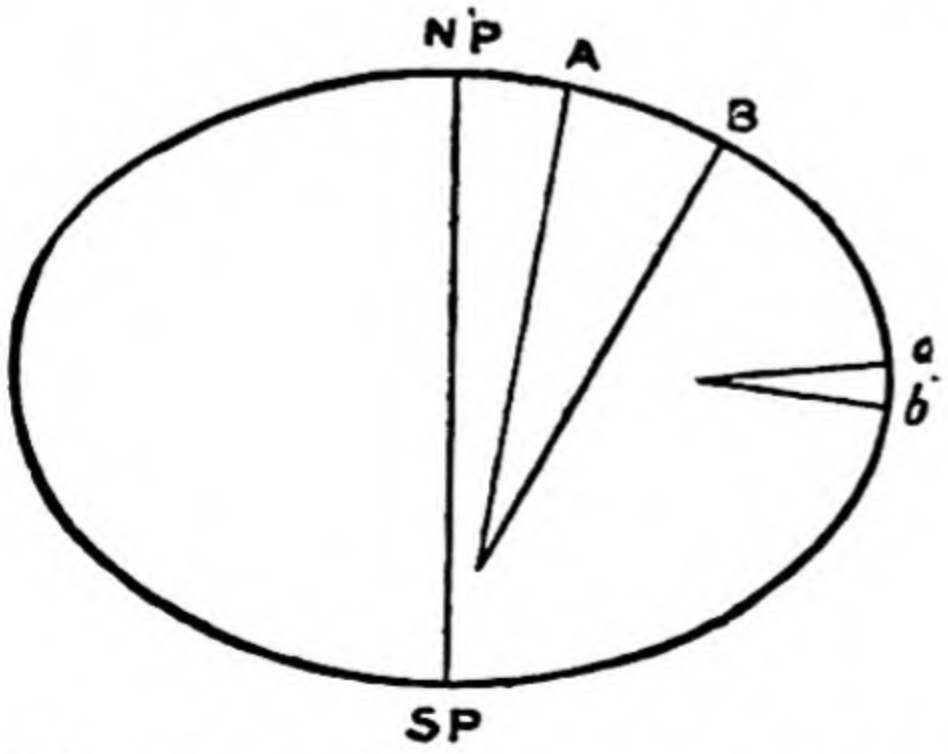


FIG. 21.—SHOWING THAT THE EARTH IS FLATTENED AT THE POLES.

(*a*) When astronomers measure degrees on a meridian in high latitudes they find that they are slightly longer than degrees near the equator—about $\frac{7}{10}$ mile. They must therefore be part of a larger circle than the degrees near the equator, for, the larger the circle, the longer is $\frac{1}{360}$th part of it and the flatter the curve. This is illustrated in fig. 21, where the flattening at the poles is much exaggerated. A B subtends the same number of degrees as *a b*, but it is plainly an arc of a larger

circle, whose centre is at a greater distance. Hence the length of A B is greater than that of *a b*.

(*b*) Making allowance for the decrease of centrifugal force due to the earth's smaller rate of motion, it is found that the force of gravitation near the poles, as indicated by the weight of a body, is greater than that near the equator, and this can only be explained by the fact that we are nearer the earth's centre at the poles than at the equator—13½ miles nearer—for the polar *diameter* is 27 miles less than the equatorial diameter (*see* Par. 1).

(As already remarked (Par. 3), a degree of *longitude* gradually diminishes from 69 miles at the equator to zero at the poles, as such a degree is measured in an east and west direction along a parallel of latitude, and these parallels get shorter and shorter as we approach the poles.)

CHAPTER II

THE ATMOSPHERE: ITS COMPOSITION, PRESSURE AND TEMPERATURE

12. The **Atmosphere** is the invisible envelope of air that surrounds the earth on all sides, reaching far above the summits of the highest mountains. It is drawn to the earth by the force of gravity, and shares in the movements of rotation and revolution. It is the region in which many wonderful phenomena of Nature take place—clouds, fog, rain, snow, hail, winds, and storms. The atmosphere is necessary for the respiration of animals and plants, and it takes part in the distribution of the light and heat of the sun.

13. **Composition of the Atmosphere.**—The atmosphere or air is a mixture of several gases not chemically united, and possessing the properties of weight, expansibility, and diffusibility. **Dry** air consists of **four** gases, mixed together in unequal proportions—nitrogen, argon, oxygen, and carbonic acid or carbon dioxide. In 100 volumes of dry air we have:—

Nitrogen	78·00
Oxygen	20·96
Argon and other inert gases	1·00
Carbonic acid	0·04
	100·00

Nearly pure nitrogen can be obtained by burning phosphorus in dry air in a closed vessel. The phosphorus unites with the oxygen to form a powder, which falls down, and the gas left is mainly nitrogen. Nitrogen is an invisible gas having

hardly any active properties, and serving mainly to dilute the active oxygen. Atmospheric nitrogen, however, is not quite pure, for besides containing a trace of carbonic acid, it contains the inert gas argon, and the similar gases helium, neon, krypton, and xenon in about the proportion indicated, together with some hydrogen.

Although nitrogen forms nearly four-fifths of the atmosphere, oxygen is the most important constituent. This colourless gas is necessary for all living beings, and animals deprived of it soon die. It is also necessary for all kinds of combustion, which is merely the active chemical union of a substance with this gas. A modification of oxygen, termed ozone, exists in small traces in pure air, and its intense activity, with its use as a purifier, is remarkable. The carbonic acid of the air is a compound colourless gas formed by the union of oxygen with carbon. It is largely given off by all animals in breathing, and is also a product of the burning of all animal and vegetable matter. Yet the general composition of air remains constant, for the green parts of plants, in the presence of sunlight, take in the carbonic acid, retain the carbon and set free the oxygen. In this way plants keep up the purity of the atmosphere.

Water-vapour is also always present in the air, for water evaporates from the surface of the rivers and seas, as well as from moist ground at all temperatures, passing into the air as invisible vapour. The higher the temperature, the more rapidly does evaporation take place. This is seen clearly on any summer day after a shower of rain. The amount of water-vapour in the air varies greatly, for, the greater the temperature of the air, the more water-vapour can it hold. Thus, at 40° F. a cubic foot of air can hold about 3 grains of water-vapour; at 50° F., about 4 grains; at 60° F., about 6 grains; at 70° F., about 8 grains; at 80° F., about 11 grains. When air contains its full amount of water-vapour it is said to be *saturated*. Usually the atmosphere contains from 1 to 1½ per cent. of water-vapour, being seldom completely saturated, and never perfectly dry. If the quantity be much above or below 70 per cent. of the amount required for complete saturation, it is unpleasantly moist or dry. The presence of water-vapour in the air can be readily shown by exposing such a hygroscopic substance as caustic potash or calcium chloride. Instruments for estimating the quantity of water-vapour in the air at any given time are called **hygrometers** (fig. 22). (*See* Glossary, 'Humidity.')

Besides the above substance, air contains dust particles, and

in the neighbourhood of towns traces of other gases. The dust particles play an important part in the condensation of aqueous vapour, being the nucleus around which condensation takes place. (*See* Glossary, 'Dust.')

14. **Pressure of the Atmosphere.**—The mixture of gases constituting air possesses **weight,** as can be shown by weighing a glass globe when full of air, and again when exhausted by means of an air pump. Having weight it gives rise to pressure, transmitting this pressure in all directions like other fluids. This pressure is always at right angles to any surface, and gets less the higher we ascend from the earth, for the air becomes thinner or rarer as we rise higher. Atmospheric pressure not only varies at different heights, but there are small variations of pressure at the same spot day by day, because the air, being elastic, may expand or contract, and thus a given volume may contain less or more air particles. At the sea-level, however, the pressure of the air is usually such that it will sustain a column of mercury 30 inches high. This is equal to a pressure of nearly 15 lb. on a square inch; so that a person of ordinary size sustains a pressure of about 14 tons. As this pressure is exerted equally in all directions, and as the tissues of the body are constituted to live under it, no inconvenience is felt.

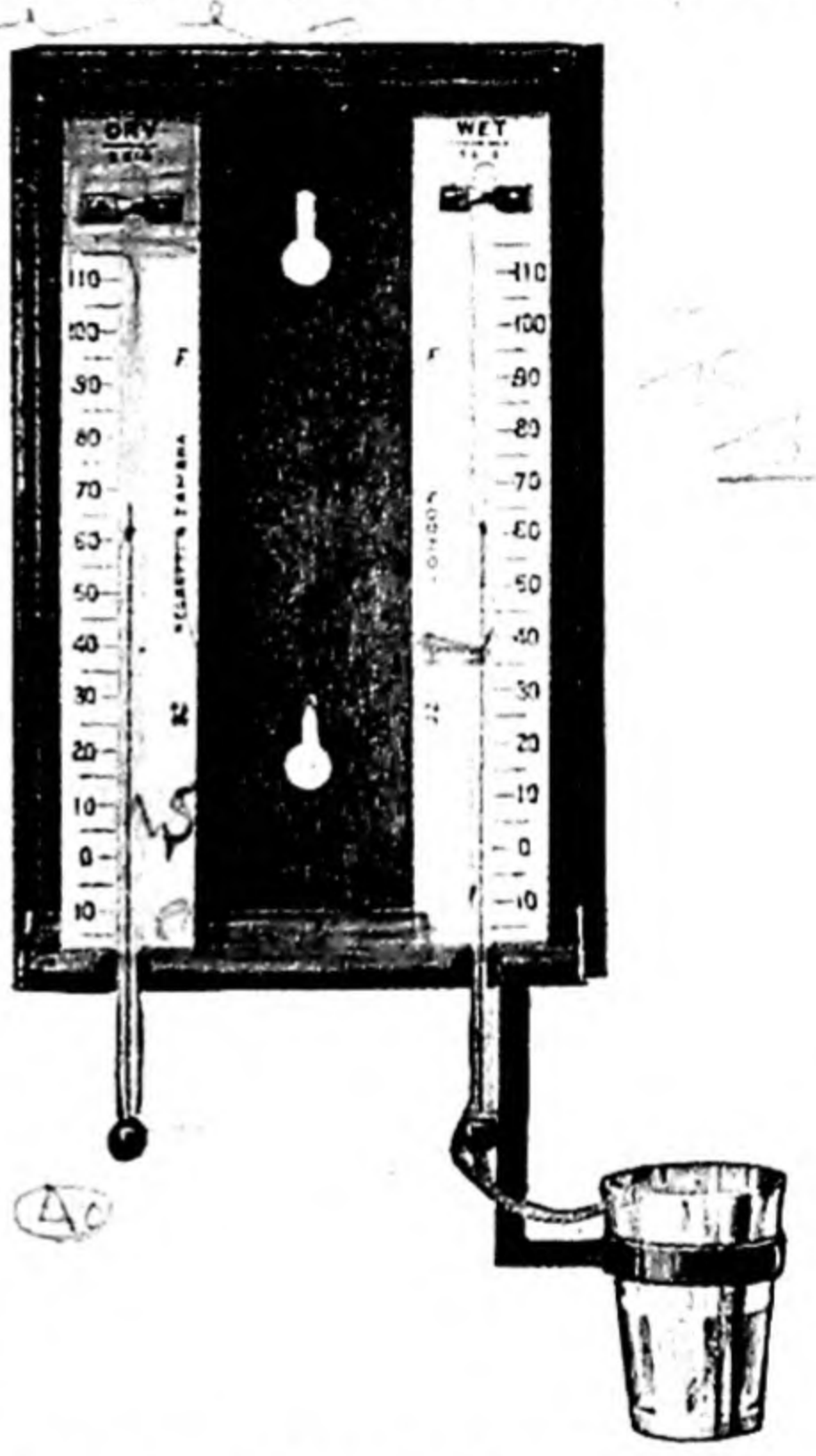


FIG. 22.—MASON'S HYGROMETER, OR THE DRY AND WET BULB THERMOMETER.

The atmosphere becomes rarer as we ascend and leave the denser layers below us, and, consequently, the pressure gets less. Near the sea-level a fall of 1 inch in the barometer corresponds to a rise of 900 feet, and thus the barometer can be used to measure small heights. At great heights the fall is more rapid. On the summit of Mont Blanc the pressure is only a little more than half that at the sea-level, showing that one-half the atmosphere is below the height of $3\frac{1}{2}$ miles. On the summit of Chimborazo, 20,500 feet high, Mr. Whymper found a pressure of only 14·1 inches. Though the pressure diminishes so greatly that at a height of 14 miles $\frac{15}{16}$ths of the atmosphere is below, yet it is not possible to say exactly to what **height** the atmosphere reaches. Observations on twilight show that it produces effect on light at 40 miles high. Beyond this there must be air sufficient to kindle meteors, for their flash has been noted beyond 200 miles.

The upper region of the atmosphere, above 10 kilometres or 6 miles, is called the stratosphere, and is separated from the troposphere or lower region by a boundary region known as the tropopause.

15. **The Barometer.**—Take a glass tube about 33 inches long, closed at one end and open at the other; fill it quite full with mercury, and, closing the open end with the thumb, invert the tube in a cup or cistern of the same liquid. Removing the thumb, we see that the mercury sinks in the tube a short distance, leaving a vacuum above. It then remains stationary, being held up by the pressure of the air on the surface of the mercury in the basin; for this pressure is transmitted through the mercury in the basin to the under surface of the mercury in the tube. Such a tube and cistern is called a mercurial barometer, and the difference of the height between the surface of the mercury in the basin and that in the tube is the measure of the atmospheric pressure. Thus, a barometer in its simplest form consists of a tube dipping into a cistern of mercury, and containing a column of that liquid supported by the atmospheric pressure which it serves to measure. It is usually attached to a wooden frame, and a graduated scale divided into inches and fractions of an inch is placed parallel with the tube, the upper part of which need alone be visible. As the atmospheric pressure varies the height of the mercurial volume varies. Mercury is forced into the tube, and the column rises when the pressure increases, while the column sinks as the pressure diminishes. Hot air is lighter bulk for bulk than cold air, and air containing much water-vapour is lighter than dry air. Hence in the British Islands the barometer rises during dry easterly winds and falls during damp westerly winds. Thus the pressure of the atmosphere at any one place may vary from hour to hour during the same day. (For 'Barometric Corrections,' *see* Glossary.)

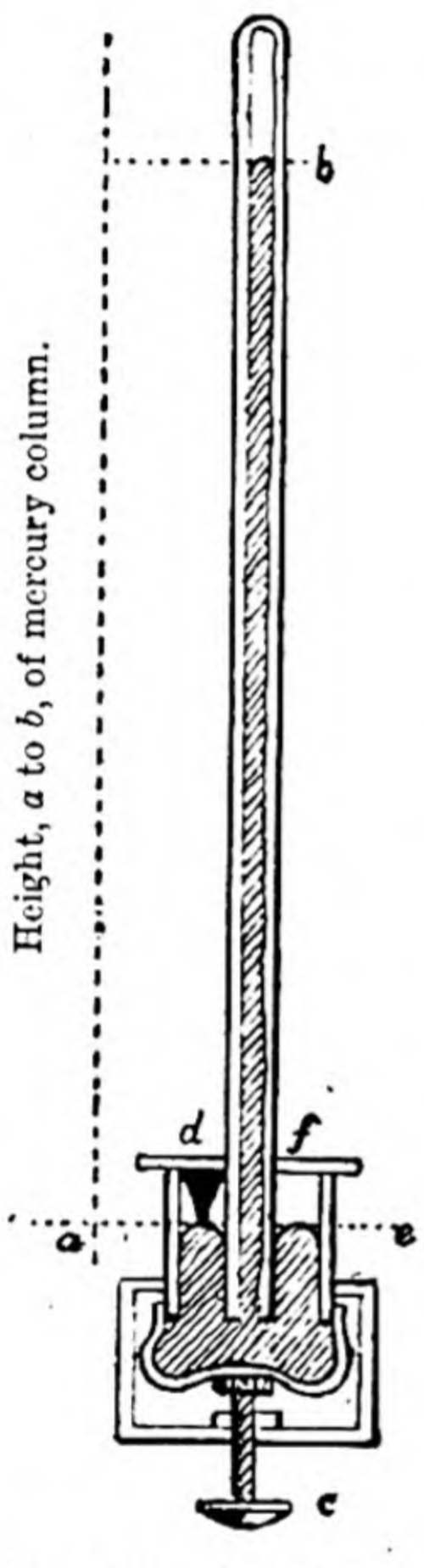


FIG. 23.—DIAGRAM SHOWING A FORTIN'S BAROMETER.

16. **Changes in Barometric Pressure.**—We have learnt that not only does the pressure of the atmosphere vary with height above the sea-level, but that it may also vary at different places, or at the same place at different times. The two chief causes of this variation are (1) the varying temperature of the air, (2) the varying quantity of aqueous vapour in the air. Remembering that the heating power of the sun's

rays is greatest at the equator and decreases towards the poles, it is easy to understand that the heated air near the equator expands, rises, and overflows, and that, therefore, the pressure near the equator is less than in higher latitudes. Owing to the spherical form of the earth, the air flowing towards the poles moves into a region becoming narrower and narrower, so that it is at last brought down near the 30th parallel of latitude, where we have a region of high pressure on each side of the equator. In regions like the Antarctic Circle, where there is generally much water - vapour, the barometric pressure is below the average. Thus, taking the globe as a whole, we have two belts of high pressure passing round the globe, at about 30 degrees from each side of the equator, a belt of low pressure in the tropics, and two regions of low pressure near the poles.

Land and water also cause local differences of pressure, as the sun's heating effects on land and water are different, the variations of temperature in water being much less than in land. Seasons also cause differences of temperature and differences in the amount of water-vapour, and thus affect atmospheric pressure. **Isobars** (Gr. *isos*, equal ; *baros*, weight) are lines drawn through places having an equal barometric pressure during a certain period. They may be drawn for each month or season, or for a year.

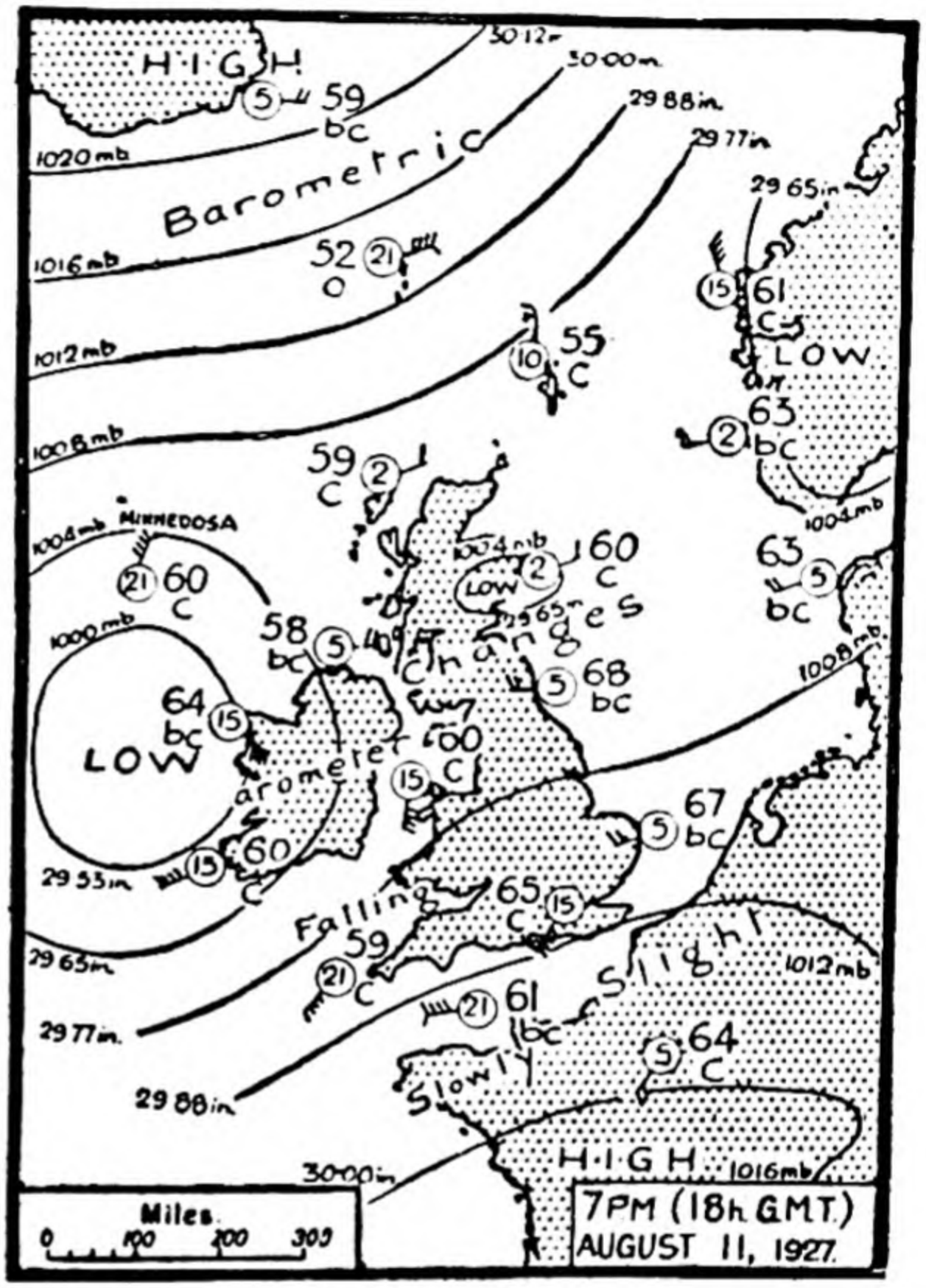


FIG. 24.—WEATHER CHART SHOWING A TYPICAL CYCLONIC SYSTEM MOVING SLOWLY EASTWARDS ACROSS THE BRITISH ISLES. Figures in circles show strength of wind in miles per hour; other figures are temperature (in degrees Fahrenheit). (*Reproduced from* The Times, *London, by permission of the Proprietors.*)

In *The Times* newspaper there is each day a chart of North-Western Europe, showing the isobars, the temperature, and the direction and force of the wind for the previous day.

17. **Temperature of the Air.**—This is measured by means of thermometers placed in suitable screens.

The air receives its supply of heat from the sun in two ways,

directly and indirectly. In the first place, an amount, varying with the humidity of the atmosphere, is absorbed as the sun's radiant beams pass through to the earth. Dry air is nearly entirely transparent to the sun's rays, absorbing little, but air charged with water-vapour readily absorbs certain rays of sunlight. Many of the rays, however, pass through the atmosphere without loss, and are absorbed by the land and water of the earth's surface, and then the air in contact with these surfaces becomes warmed. From the land surface, and more slowly from the water surface, of the earth some of the absorbed heat is then again radiated into the atmosphere, and these dark heat rays are readily absorbed by the water-vapour and dust particles in the atmosphere, and so communicate heat to the air.

The chilling of the atmosphere at night by radiation is checked, the moisture and dust-motes acting as a screen and retarding the escape

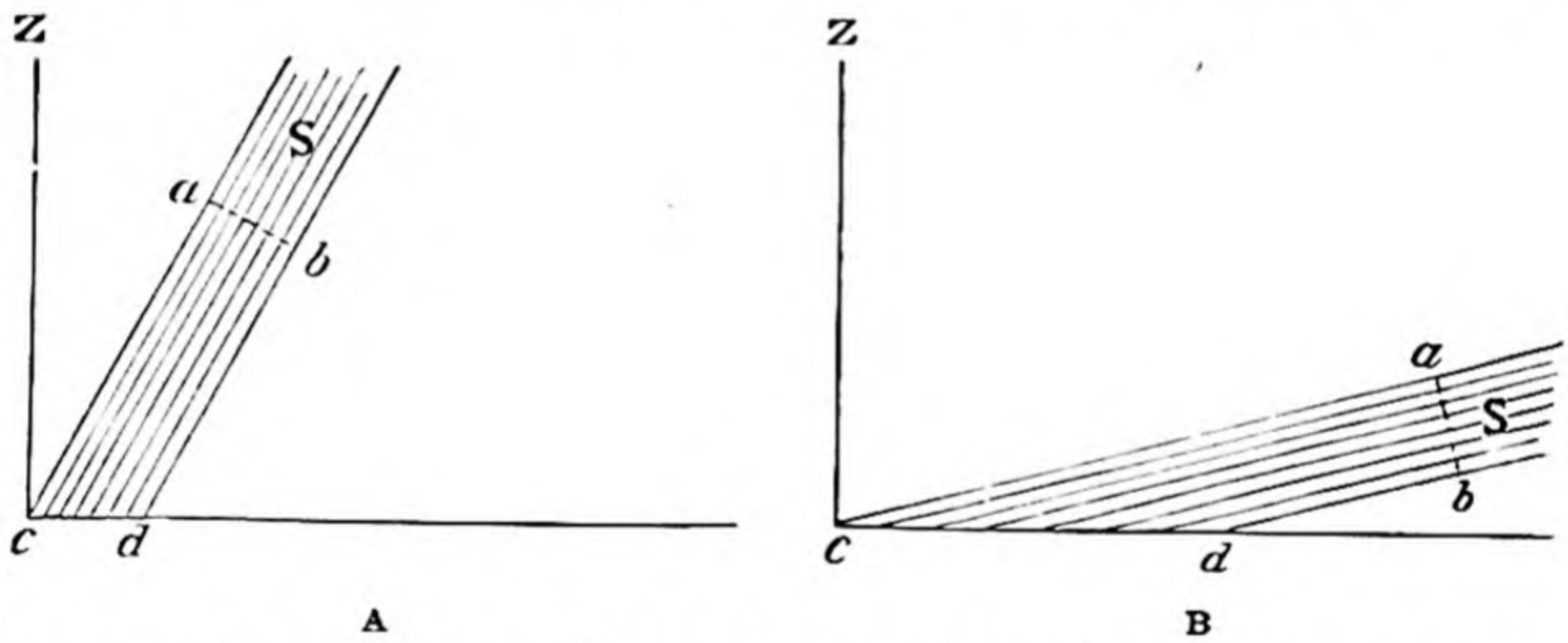
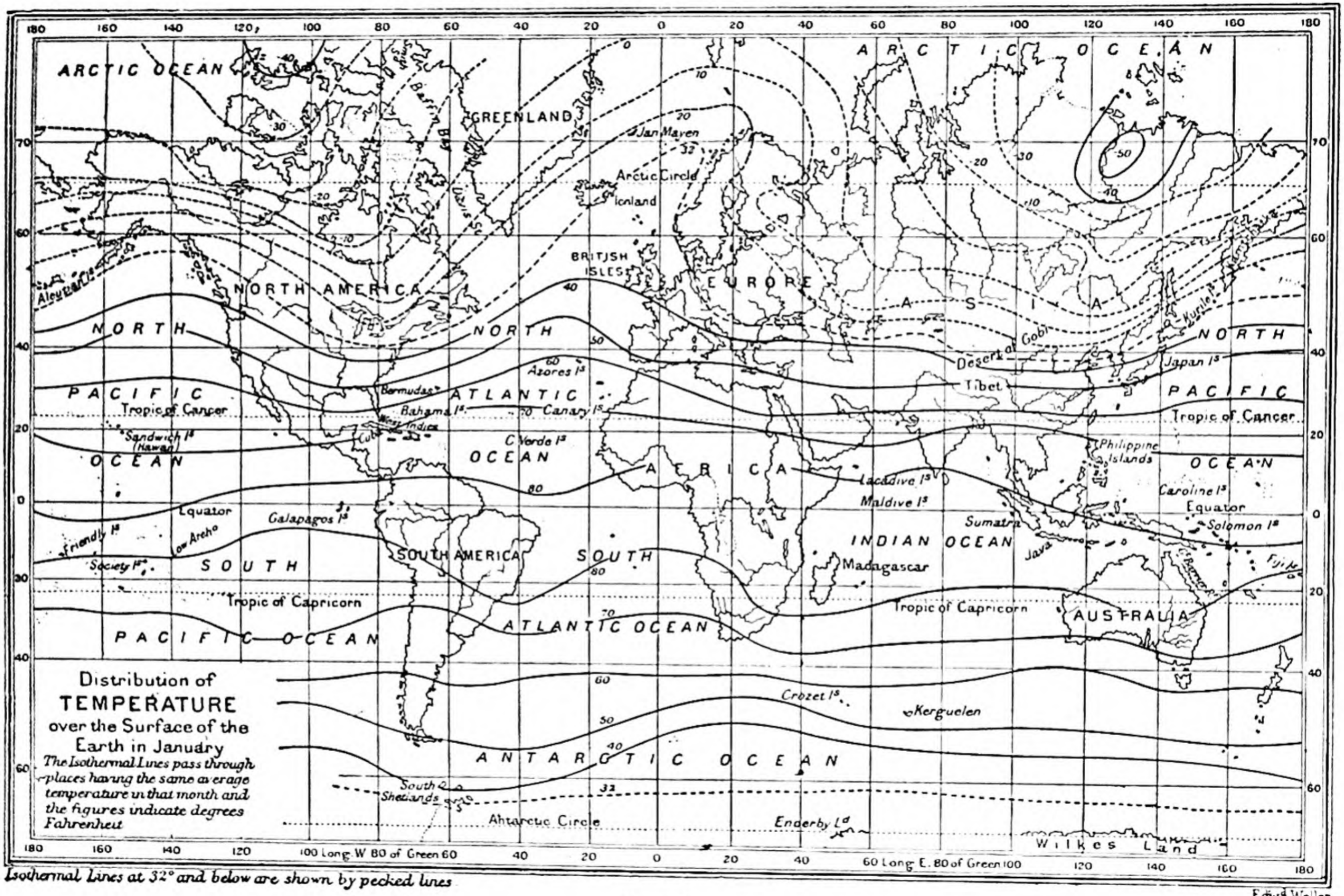


FIG. 25.—SHOWING THE DIFFERENCE IN THE DISTRIBUTION OF THE SUN'S RAYS AT LONDON AT MIDSUMMER (A) AND AT MIDWINTER (B). The zenith distance of the sun at noon is about 28° at midsummer in the latitude of London, and about 75° at midwinter. Its altitude is therefore $90° - 28° = 62°$ in the former case, and $90° - 75° = 15°$ in the latter case.

of heat from the earth's surface. Gradually, however, the warmth passes from the lower into the upper atmospheric strata, and is then lost by radiation into the cold regions of space.

It is easy to see why the air is warmer at noon than in the morning or evening, for the rays in the morning or evening not only pass through a much larger thickness of air, and thus suffer more absorption before they reach a particular place, but a beam of a certain size is spread over a larger surface the more obliquely it strikes the ground. The difference, in fact, is due to the same causes as the differences in the noonday rays as experienced at midsummer and midwinter. (The *mean* temperature of any period may be found by taking a number of observations at suitable intervals, and dividing these temperatures by the number of observations.) If we ascend above sea level through

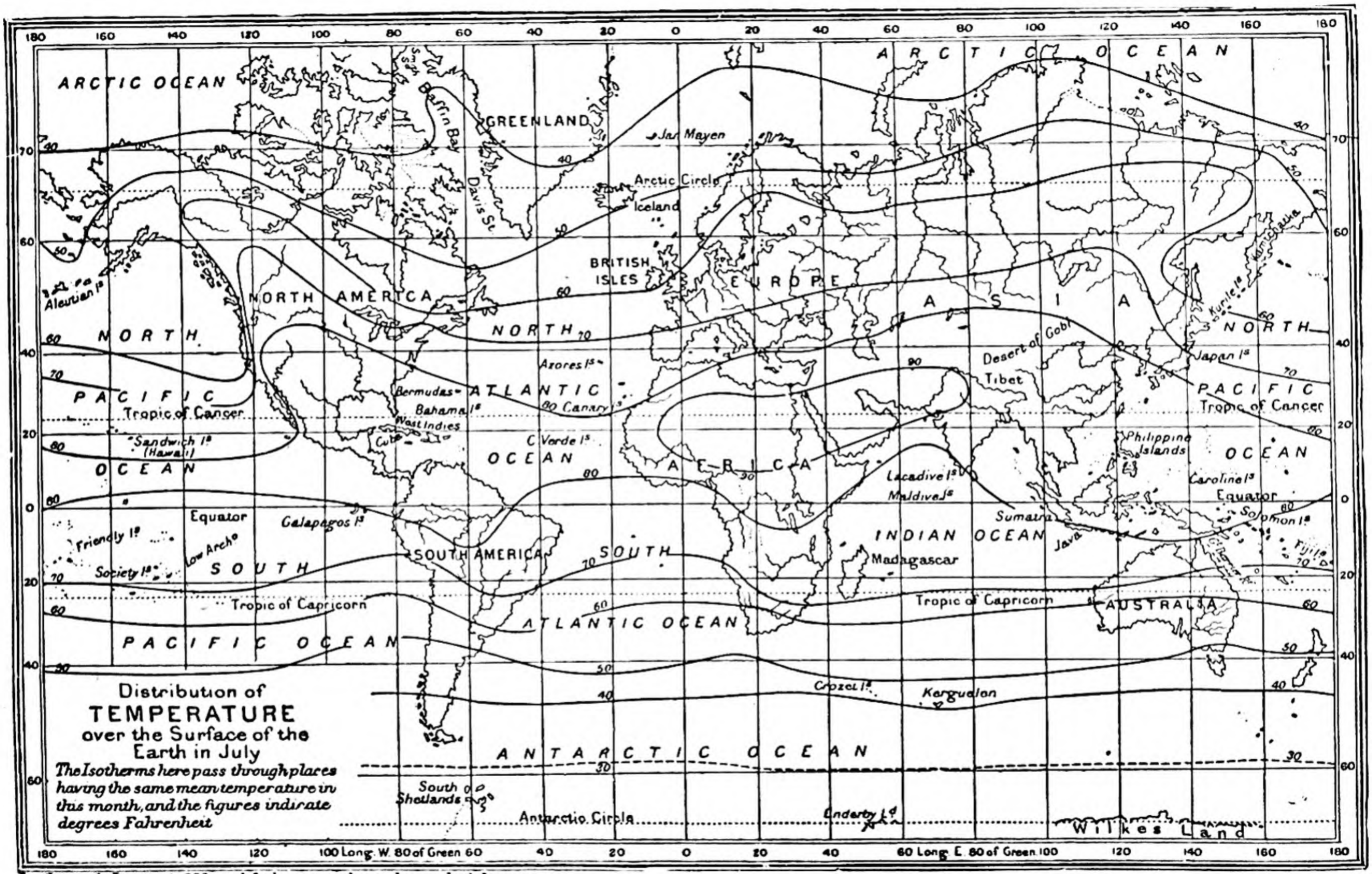


Distribution of
TEMPERATURE
over the Surface of the
Earth in January
The Isothermal Lines pass through places having the same average temperature in that month and the figures indicate degrees Fahrenheit

Isothermal Lines at 32° and below are shown by pecked lines

Edwd Weller

MAP 1



Isothermal Lines at 32° and below are shown by pecked lines.

Map 2.

quiet air, we find as a rule the temperature of the air decreases, the change due to difference of altitude being a decrease of about 1° F. for every 300 feet. Hence temperature observations at places having different altitudes are for the sake of comparison, and the formation of isotherm maps, corrected to sea-level by *raising* the temperature observed 1° F. for every 300 feet of altitude. (*See* Question 189.)

18. **How far the Temperature of the Air depends on Latitude.**—Remembering that the more we recede from the equator the more oblique, and therefore the less effective for heating the air, become the sun's rays, we can understand why, generally speaking, the temperature at the sea-level diminishes as we pass towards the poles. Were there no other cause this diminution would be regular, and every place in the same latitude would have the same temperature. But this is not the case. When we examine a chart of the world on which isotherms (Gr. *isos*, equal; *thermos*, heat) are drawn through places having the same temperature of the air during a given period, we see that these lines are very irregular, and vary considerably at different seasons, especially over continental areas. On referring to the maps on which the isothermal lines are drawn for January and July, it will be seen how very irregular these lines are in the northern hemisphere, and how comparatively regular they are in the southern hemisphere, where there is a great preponderance of water. These lines thus show that temperature depends more on latitude in the great oceanic areas of the globe than in the continental areas, or in the regions where the sea and land come together. As a rule, the northern hemisphere is seen to be warmer on the average than the southern, except in high latitudes, where the converse is true, the land also being generally warmer than the sea in low latitudes, but colder in higher latitudes. They also show that the district of greatest heat, especially in summer, is the interior of continents, the deserts of Africa and Persia having a July temperature of 90°. The temperature of the sandy *ground* in these parts is often above 160° F. There must, therefore, be some other causes modifying the effect of position as regards the equator. Among these are the prevailing winds, distance from the sea or other large body of water, position of mountain chains, and the altitude of the land. These will be discussed in speaking of **Climate.**

CHAPTER III

WINDS AND OTHER ATMOSPHERIC PHENOMENA

19. **Winds.**—Wind is air in motion, and the cause of winds is the unequal distribution of pressure in the atmosphere, the air moving in consequence of gravity from regions of high pressure to regions of low pressure. The greater the difference of pressure as indicated by the barometric **gradient,** the stronger is the wind. The gradient is measured by the number of hundredths of an inch in difference of pressure at a distance of fifteen nautical miles. Differences of pressure arise either from differences of temperature or from differences in humidity

(moisture), for warm air is lighter than cold air, and air containing much water-vapour is lighter than dry air. Some winds are **constant** or regular, others **periodical**, and others **occasional** and **variable.** Of the **constant** winds, the trade winds are the best example; of **periodic** winds, the monsoons of the Indian Ocean and Australia are well known.

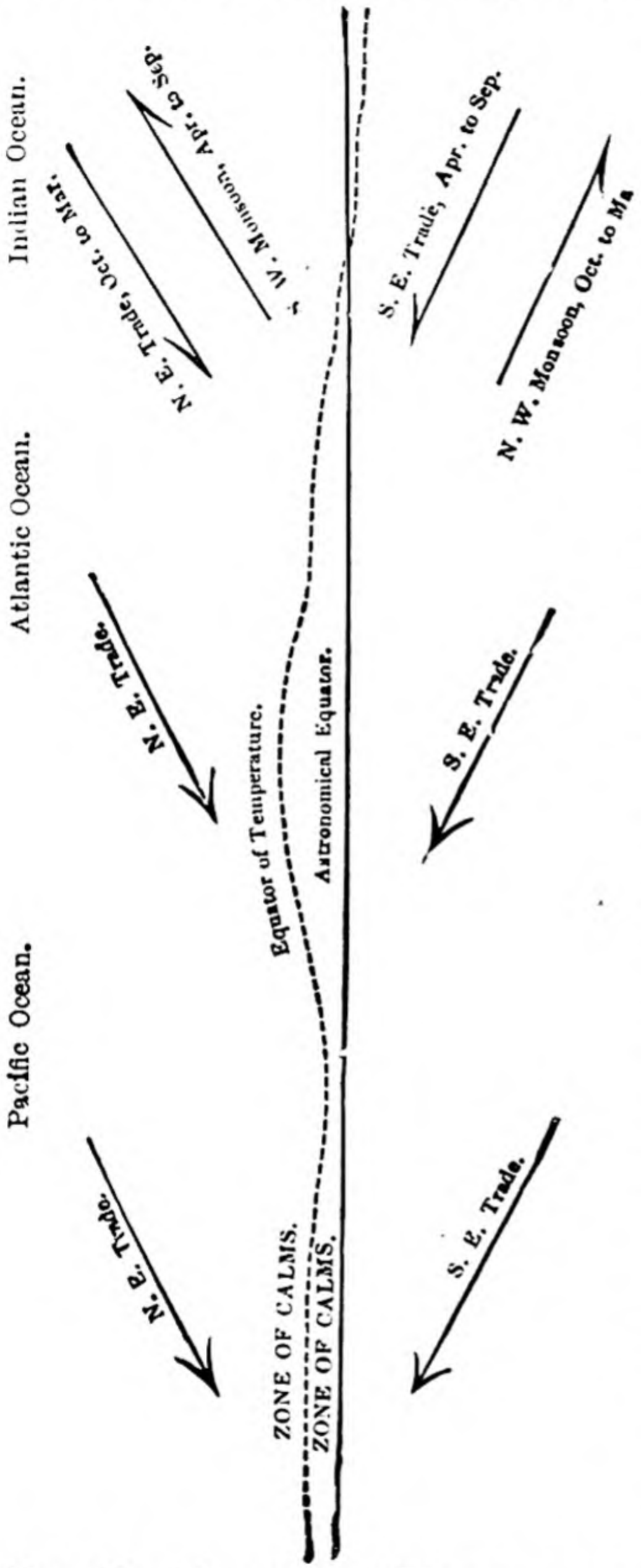


FIG. 26.—DIAGRAM OF WINDS WITHIN THE TROPICS.

20. **Trade Winds.**—The air lying over the Torrid Zone of the earth becomes heated by contact with the surface of the earth that receives the nearly vertical rays of the sun (Par. 17). There is also great evaporation from the water surface of this zone. This heated and moisture-laden air rises upwards, flows off above towards the poles, and cooler air from regions north and south of the equator flows in along the surface to take its place. There thus arises a belt of low pressure near the equator a few degrees in breadth, known as the **zone of calms** or **doldrums,** a belt characterised by frequent heavy rains and violent thunderstorms. This belt lies a little to the north of the equator, as the **thermal equator**, or line of greatest temperature, owing to the greater amount of land in the northern hemisphere, is a few degrees north of the equator. But this line and zone shift their positions a little, according to the season, advancing towards the north in summer, as the sun is then vertical north of the equator, and receding towards

the south in winter, as the sun is then vertical south of the equator. The expanded and rising air of the calm belt leads to the steady inflow of surface winds from regions of greater pressure in higher latitudes towards the equator. If the earth were at rest, a north wind would prevail at the north side of the calm belt, and a south wind on the south side of the calm belt. But the **earth's rotation** deflects these winds to the right in the northern hemisphere and to the left in the southern, their directions becoming more and more easterly as they approach the equator. These regular winds from the north-east on the northern side of the equator, and from the south-east on the southern side of the equator, constitute a regular system of currents known as the **trade winds.**[1] Over the land, the greater friction and the irregular distribution of temperature disturb their uniformity, and hence they are most marked in the open sea, where the surface temperature is more uniform.

The **Trade Winds** are thus constant winds blowing in a broad belt on each side of the equator towards the equatorial low-pressure belt of calms (figs. 26, 27). The belt of north-east trades moves north in the northern summer as the sun moves north, the northern limit then reaching beyond 40° N., and bringing the European districts bordering the Mediterranean under their influence. In winter, however, their northern limit falls short of 30° N., so that these areas are then under the influence of the south-westerly rainy winds. A similar movement to a less extent of the belt of south-east trades occurs with the seasons of the southern hemisphere. The trade winds die out as they approach the belt of calms.

As the trade winds move from colder to warmer latitudes they are dry winds over the sea and low coastal plains. Where they meet high lands and are forced up, they are cooled by ascension, so that their moisture is condensed and falls as rain or snow. An illustration of this is furnished by the heavy rainfall on the eastern slopes of the Andes in the S.E. trade wind zone of Brazil. (*See* Map 4, p. 57.)

Beyond the borders of the trade winds in both hemispheres the prevailing winds are from the south-west or north-west, but these westerly winds are not so regular as the trade winds. These westerly winds arise in great part from the upper currents that flow from the equator, and then descend to the surface about the thirtieth parallel of latitude, where they produce the **calms of Cancer** in the northern hemisphere and the **calms of Capricorn** in the southern. Continuing northward or southward, and being deflected to the right or left, according to the

---

[1] Winds are named according to the quarter *from* which they come, a north-east wind coming from the north-east and blowing towards the south-west. Currents are named according to the direction *towards* which they flow, a north-westerly current flowing towards the north-west, but coming from the south-east. (*See* Glossary, 'Ferrel's Law.')

hemisphere (north or south), by the earth's rotation, they form the **westerly winds** or **S.W.** and **N.W. anti-trades** (or Variables) of temperate latitudes (*see* fig. 27). These anti-trades are most regular in the southern hemisphere, where there is little land to cause a disturbance, and in the Pacific and Indian Oceans between latitudes 40° and 50° S. they are so strong and steady as to be called the 'Roaring Forties.' (*See* Glossary, 'Planetary Winds.')

21. **Monsoons** are periodical or seasonal winds that blow in alternate directions in some parts of the trade-wind regions. They are caused by difference of atmospheric pressure between areas of land and sea, such differences being due to seasonal changes of temperature. The

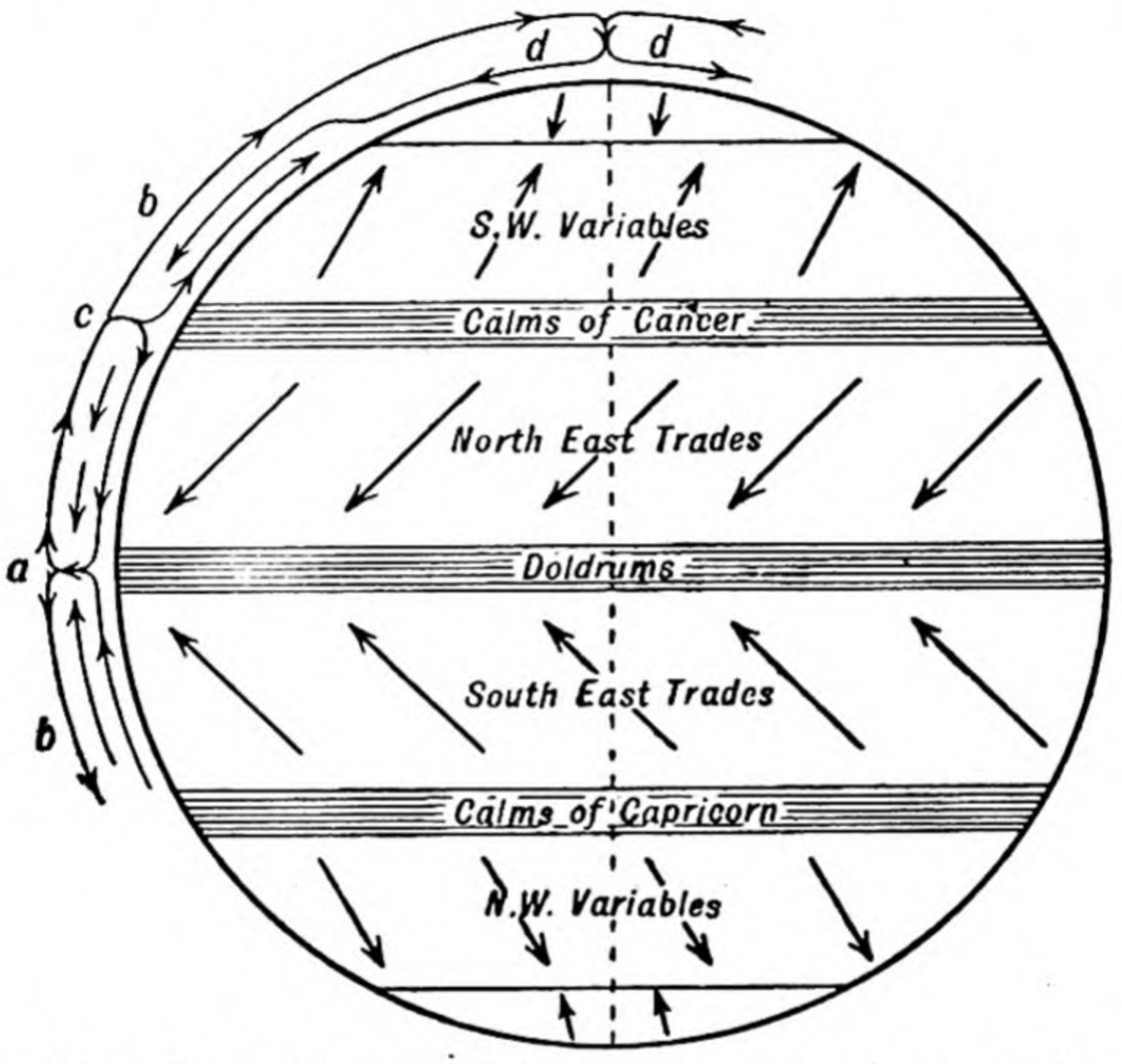


FIG. 27.—At *a* the heated air rises, to flow away towards the poles in the upper atmosphere; at *c* it descends, part returning to join the descending cooler air from the poles, and to help to form the north-east trades, and part passing onwards to form the south-west anti-trades. (*See* Glossary, 'Anti-trades.')

monsoons of the Indian Ocean and adjacent lands (India, Burma, Malay, Siam, and Southern China) are best known. During the cooler part of the year, November to February, a **north-east wind** called the **north-east monsoon** blows from these lands and over the adjoining seas. This is, in fact, the regular N.E. trade-wind of this hemisphere. But in summer the north-east monsoon is reversed, for the sun's heat upon the Southern part of Asia and the high table-lands of the centre leads to a rise of air and to regions of atmospheric pressure much lower than the pressure area of the Indian Ocean, and therefore air flows from the Indian Ocean to the regions of lower pressure over the land, and being deflected to the right by the earth's rotation becomes the **south-west monsoon.** This south-west monsoon is also called the wet monsoon,

and blows from the Arabian Sea and the Bay of Bengal over India and Indo-China from May to September, and being charged with vapour from warm seas supplies rain to these countries, a very heavy rainfall where it is greatly cooled by expansion on being forced up the slopes of the Western Ghats and Himalayas. This S.W. monsoon is often called **the monsoon,** and it is usually a much stronger wind than the other monsoon.

The winter or N.E. monsoon is, like the trade winds, generally a dry wind, though the part that comes across the Bay of Bengal takes up sufficient water vapour to supply rain to the hills of Ceylon. The change of monsoons is often accompanied by violent storms.

Monsoon effects, due to similar causes, prevail on the north-west of Australia and in the Gulf of Guinea.

22. **Variable Winds.—Land and Sea Breezes.**—The regularity of the winds is interfered with in many parts by several causes, the chief of which is the unequal heating of the land surface and the surface of

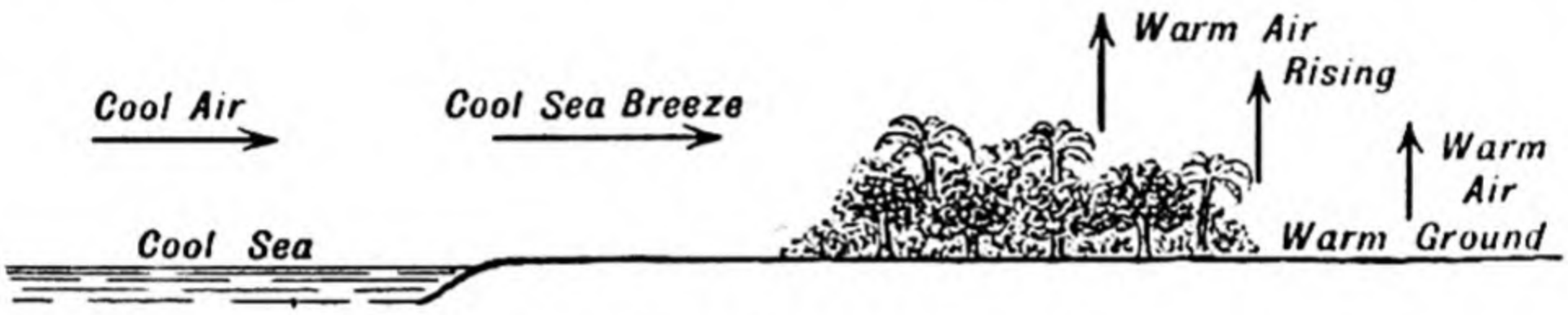


FIG. 28.—SEA BREEZE BY DAY

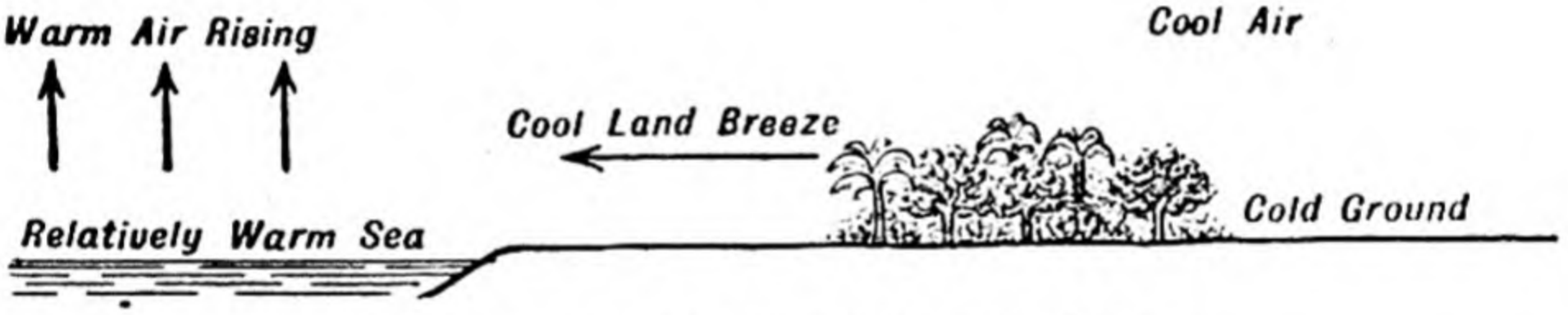


FIG. 29.—LAND BREEZE BY NIGHT.

the sea. Land is quickly heated by the sun's rays and quickly parts with its heat, for this heat does not penetrate far, and is soon radiated at night. The sea heats slowly, as the heat penetrates to a greater depth, and thus affects the surface less. Further, water requires four times the quantity of heat to raise it the same number of degrees as the land. From a water surface the heat radiates slowly when the sun is not shining, so that the air resting over it does not change its temperature so much as the air resting over the land. The irregular distribution of land and water on the surface of the globe thus affects the general circulation of the air resting over the earth.

Land and sea breezes are local movements of the air felt on sea coasts when not overpowered by other winds. They are most distinctly felt in tropical countries, especially on islands and peninsulas. In our own country they are often overpowered by a strong general wind. The temperature of a land surface undergoes far greater changes in twenty-four hours than the sea surface, owing to the different manner in which the sun's heat affects the land and water, and also to the different radiating power of the two surfaces. During the day the land surface becomes hotter than the sea surface, and the air resting

upon it rises and flows off above, while the cooler air comes in from the sea as a **sea breeze**. As the sun sets the land surface quickly cools, until it attains the same temperature as the sea when calm prevails. An hour or two before midnight the land has cooled so rapidly that it is now colder than the sea. The air over it contracts, and its pressure becomes greater than the warmer air over the sea. Hence it is that this heavier air flows from the land to the region of lower pressure over the sea, and a **land breeze** blows until 6 or 8 o'clock A.M.

23. **Cyclones and Anti-Cyclones.**—The variable winds of the north temperate zone either blow, as a rule, inwards towards a centre of low pressure, or outwards on all sides from a centre of high pressure. A wind system in which the wind blows spirally around and in towards a centre of low pressure is called a **cyclone** (Gk. *kuklos*, a circle), as the isobars outside the centre have a more or less circular shape. A wind system with light winds flowing outwards from a centre of high pressure is known as an **anti-cyclone.** 'The direction in which winds blow spirally inwards in a cyclone is (in the northern hemisphere) opposite to that of the movements of the hands of a watch lying face upwards; in an anti-cyclone the opposite. The position of an anti-cyclone is usually pretty constant for days, or even weeks together, but that of a cyclone is constantly changing, as the centre of low pressure is always shifting.' The position of the centre of a cyclonic storm can always be found by standing with the back to the wind, when the cyclonic centre will be on the left in the northern hemisphere and on the right in the southern hemisphere. With cyclones come rain or snow, strong winds, and cloudy skies; with anti-cyclones dry and usually bright weather comes. Cyclones move on more quickly than anti-cyclones (*see* figs. 24 and 119). **Tornadoes** are local cyclones of great violence and small extent that move on rapidly and do great damage. They are usually accompanied by a great downfall of rain. When they occur at sea a funnel-shaped cloud may descend to the surface of the sea, draw up the whirling spray, and produce the phenomenon of a **waterspout.** Tornadoes are frequent in some districts of the United States, but similar whirling storms occur in other parts of the world. In the West Indies they are called **hurricanes,** and in the China Seas, **typhoons.** The **Simoom** is a hot suffocating whirlwind that often passes over the deserts of Africa and Arabia, carrying with it at times columns of hot sand.

It is now usual to distinguish between **tropical cyclones,** which are small local depressions with strong winds, and **temperate cyclones,** which are larger, of different origin and which are largely responsible for the varied weather of such countries in the westerly wind belt as the British Isles. During the Great War observations carried out by Bjerknes and other Norwegian observers led to the belief that there is a mass of cold heavy air over the Polar regions, and the outer margin of this mass is called the Polar Front. The westerly winds, blowing from warmer regions, rub along the Polar Front and give rise to large whirls or eddies just as a stream of water gives rise to eddies along its banks. These whirls of air are the 'depressions' or 'lows' or temperate cyclones and they are mainly responsible for the varied weather of temperate latitudes. Between the depressions, which naturally move in general from west to east, are wedges of high pressure or temperate anti-cyclones.

When a depression is approaching, as shown in fig. 30, the sky becomes clouded, there are strong south-westerly winds and later

rain falls but the temperature is low. Then, as the 'warm front' crosses the area the temperature rises suddenly and the weather clears.

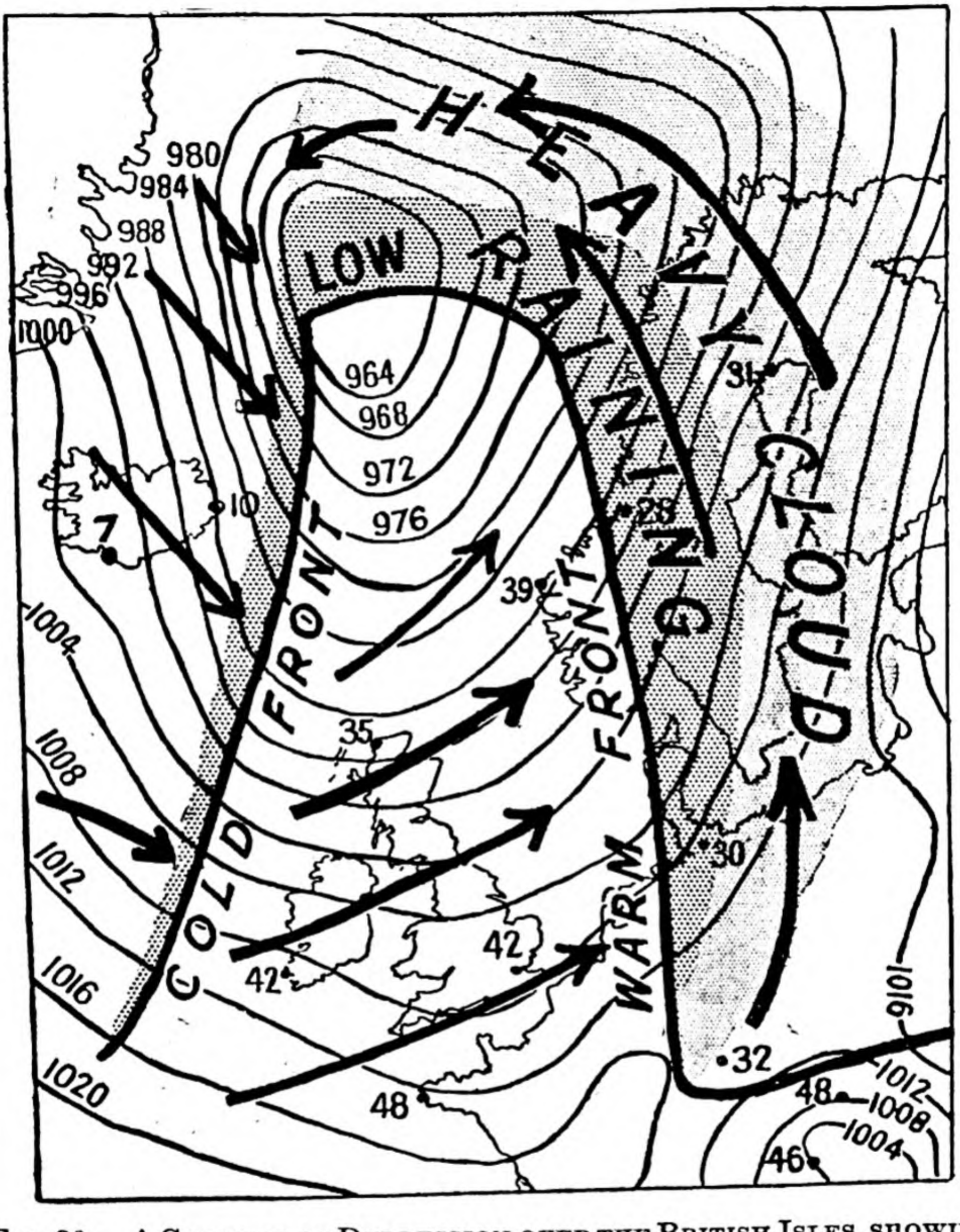


FIG. 30.—A CYCLONE OR DEPRESSION OVER THE BRITISH ISLES, SHOWING THE SYMBOLS USED IN WEATHER CHARTS. THIS CHART INTERPRETS THE OBSERVED WEATHER CONDITIONS ACCORDING TO THE POLAR FRONT HYPOTHESIS. LARGE FIGURES ARE TEMPERATURES IN DEGREES FAHRENHEIT; SMALL FIGURES PRESSURE IN MILLIBARS.

Then as the 'cold front' passes there is a sudden drop of temperature, the wind veers to north and there are 'clearing up' showers. The diagram should be carefully studied.

24. **Local Winds.**—In some districts, at certain parts of the year, winds blow that have received a special name. Thus, in countries bordering on deserts suffocating hot winds bringing fine sand blow in summer. In Arabia there is the dreaded **Simoom,** in Egypt the **Khamsin,** in Sicily the **Sirocco,** and in Spain the **Solano**—all hot and suffocating desert winds. Sometimes cold winds blow from mountains but at other times the air is warmed by compression in its descent and gives rise to the Föhn or Chinook winds—warm mountain winds.

Cold local winds also occur. Such are the **Bese,** a cold north-east wind from the Alps; the exceedingly dry cold **Puna** winds that blow in Peru for four months between the chains of the Andes; and the dust-raising **Pampero,** a violent west wind that sweeps over the **pampas** in South America. (*See also* Glossary, 'Weather Charts.')

25. **Dew.**—Dew is moisture deposited as small drops on objects at or near the surface of the earth during a clear night. Evaporation from the surface of water and moist ground is continually going on; but air at any given temperature can only hold a certain quantity of water-vapour. When unable to hold more, the air is said to be full, or **saturated**. When air is saturated with water-vapour, and a reduction of temperature occurs, part of the water-vapour is condensed, and this begins to be deposited on the surface of objects previously cooled by radiation. The temperature at which condensation begins is called the **dew-point.**

Consider what occurs during a fine, warm day and clear night, and the causes leading to the production of dew will be understood. During the day evaporation goes on freely, and the air takes up the water-vapour. Towards sunset the heat received by the earth from the sun becomes less than that radiated from the earth, and the solid objects, radiating more quickly than the surrounding air, become colder than the air. The air, thus cooling more slowly than the objects on the earth, at last reaches a temperature—the dew-point—when it is saturated with the vapour it contains. Temperature continuing to fall, the colder objects condense the moisture from the air touching them, and the deposit of dew from the air begins.

A clear night is necessary to an abundant fall of dew, as clouds check radiation from the ground and the objects upon it. Much wind checks the deposition of dew by constantly bringing into contact with objects fresh air, some of which is not reduced to the dew-point, though a slight wind helps by gradually renewing the saturated air in contact with the objects. Objects which radiate quickly lose their heat quickly, and are thus able to produce more dew on their surfaces. Hence grass and leaves are covered with dew

sooner than soil. It must be noted, however, that all the moisture deposited during the night is not obtained from the air. The leaves of plants are constantly giving off water-vapour, and some of this gets condensed on their surfaces, and adds to that deposited from the air. Water-vapour also rises from the ground, and is condensed on cold objects. When the surface on which the water-vapour is deposited is at or below 32° F. the moisture deposited is frozen. **Hoar frost** or **rime** is thus frozen moisture from the air.

26. **Fog and Mist.**—At times, in consequence of a sudden fall of temperature in the air, the aqueous vapour that it contains becomes in part condensed upon the surfaces of the small dust particles near the surface of the earth, and these, floating in the air, produce a fog. In large towns, when the dust-motes are largely intermingled with soot particles, the fog is often nearly black. Off the coast of Newfoundland frequent fogs are found, due to the meeting of the warm damp air that has passed over the Gulf Stream with the cold air from an Arctic current.

A mist is very similar to a fog, but it wets solid objects more, as it appears to consist of dust-motes on which a thicker coat of water-vapour is deposited. At night mist may often be noticed hanging over low-lying valleys. As the sun begins to warm the air in the morning, and so render it capable of taking up more moisture, the water particles are evaporated and the fog disappears.

It will be noticed that in speaking both of dew and fog condensation always takes place on the surface of a solid body. This is true of rain, snow, and other forms of condensed vapour. For condensation in the air there must always be a nucleus of **dust** (see Glossary); for vapour-laden air, if freed from all dust, can be cooled far below the dew-point without any condensation of its vapour. If, however, dust be sent in, a mist appears at once.

27. **Clouds.**—Clouds are mists formed in the higher parts of the atmosphere. When warm air ascends, it not only passes into colder regions, but the very act of expansion lowers its temperature, and the vapour it contains may then begin to condense and form a cloud. A cloud may also be formed by warm air being cooled by contact with mountains, or by warm air mixing with a cold current of air. Clouds often appear to float in the air for hours, but the water particles are continually falling slowly through the air. Meeting with warmer or drier air these particles may evaporate again. Thus condensation may be going on above and evaporation of the particles below, so that the cloud is continually changing its shape.

The average height of the clouds is somewhat above a mile, though many reach to a height of 10 or 12 miles, and others touch the earth. Several types of cloud are distinguished by their form and elevation. The highest type of cloud is a white feathery cloud, called from its appearance **Cirrus** (L. *cirrus*, a curl), or 'Mare's Tail.' It probably consists of minute ice spicules, and has an average elevation of about 6 miles. The **Cumulus** (L. *cumulus*, a heap) is the great white billow cloud, 2 to 3 miles high, common in summer, hemispherical above and flat beneath. A combination of the above two, called '**Cirro-cumulus**,' consists of smaller detached, round masses. Its resemblance to the

markings on a mackerel gives the name 'mackerel sky.' The **Stratus** (L. *stratum*, a layer) is a low cloud formed of horizontal sheets of mist, and often seen in the morning or evening of a fine day. The **Nimbus** (L. *nimbus*, dark rain-cloud) is a rain-cloud of dark or black look. It has no particular form, though the edges are usually ragged or fringed (fig. 31).

28. **Rain.**—When the tiny particles of water condensed from the vapour in the air unite they form drops, which fall to the earth as **rain.** Rain most frequently originates in the

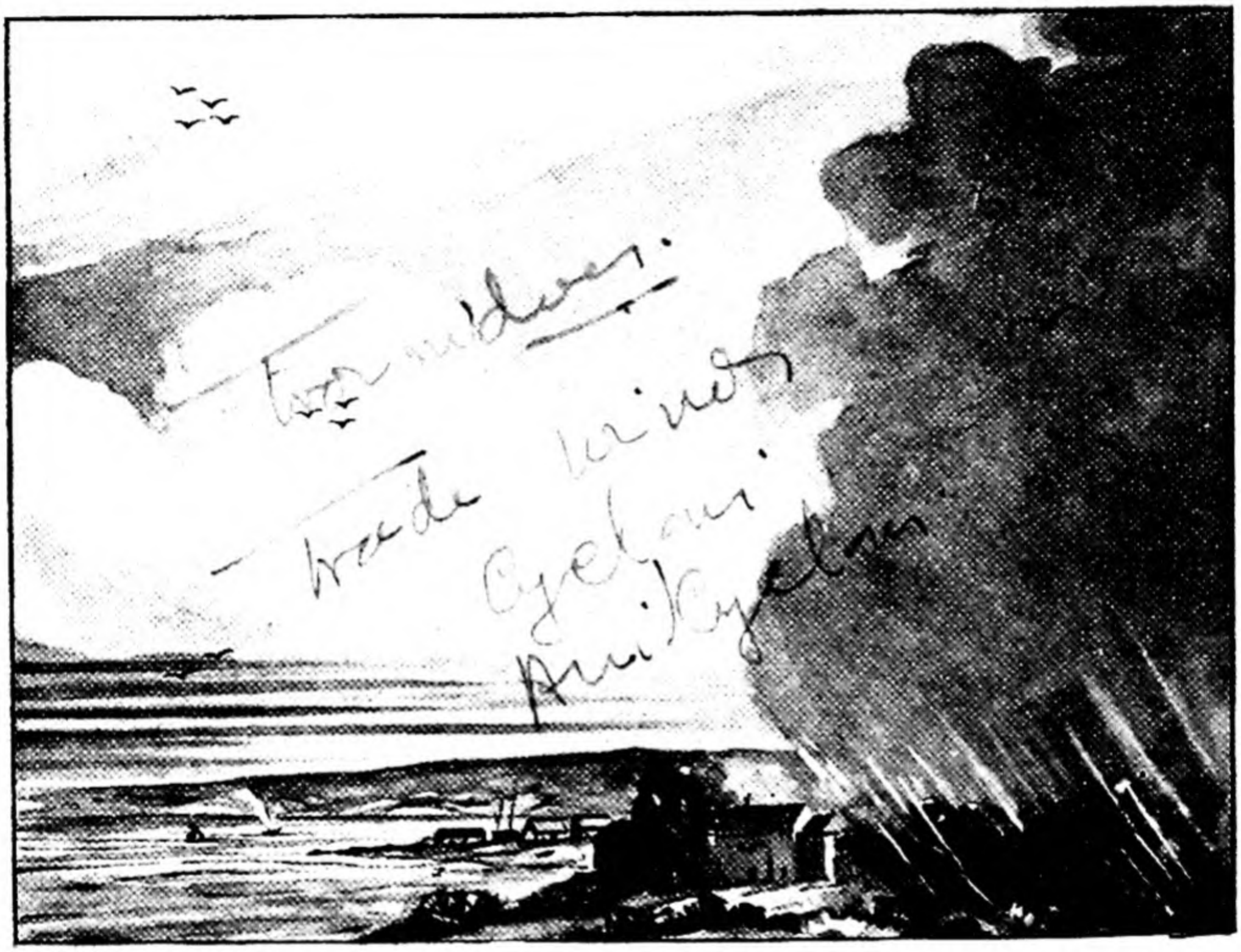


FIG. 31.—TYPES OF CLOUDS: 4 birds, Cirrus; 3 birds, Cumulus; 2 birds, Stratus; 1 bird, Nimbus.

upper part of clouds, and as the small drops descend through the cloud they unite with others, to become the larger drops that reach the earth; though if the cloud be high, and have warm, unsaturated air beneath it, the drops may be evaporated before reaching the ground. The amount of rainfall is measured by a rain-gauge, and is expressed by stating the depth in inches that would accumulate on a surface if the rain remained where it fell. A depth of 10 inches of snow is regarded as equal to a depth of 1 inch of rain. One inch of rain gives about 101 tons of water per acre. One of the chief

causes of rain is the ascent of currents of warm moist air, which are chilled by expansion as they rise.

As the sun's heat is most powerful in the tropics, there is greatest evaporation in these regions. Consequently, we have this important fact regarding the distribution of rain on the earth's surface :—Speaking generally, **the average amount of rainfall is greater near the equator, and decreases as we pass from the tropics to the poles.** Thus, at St. Domingo, in the West Indies, the average yearly rainfall is 170 inches ; at Havana, 91 inches; at Madeira, 28 inches; at Bordeaux, 26 inches; at London, 23·5 inches ; in Arctic Circle, less than 10 inches.

A very important cause of rain, and one which modifies the general statement above, is the fact that the damp and warm air that is brought to the coasts of continents and large islands is chilled by the land, especially when hills meet the course of the winds, causing the air to rise and expand, and thus become cooler. Hence its vapour is condensed ; so that the **average rainfall decreases as we pass from the coast lines that meet moist winds into the interior of the land.**

This second fact and its cause are well illustrated by the distribution of rain in the British Isles and in other temperate regions of the earth. (Remember that in the temperate zones the prevailing winds are from the west or south-west, and that between the tropics the prevailing winds are from the east, north-east trades and south-east trades (fig. 27).) The prevalent south-westerly winds that reach our isles come from warm latitudes over a great extent of sea. When these warm moisture-laden winds meet our western coasts and the mountains on the west side they ascend and are chilled. Clouds and a copious rainfall near the western coasts, especially in the mountainous parts, result ; while on the sheltered or lee side of the hills there is much less rain. The heaviest annual rainfall in the British Isles is at a spot among the Cumbrian Hills (The Stye, 170 inches), and at a place in the Northern Highlands of Scotland (125 inches). Low-lying districts on the east side of Britain have the least rainfall, and districts round the Wash and the Isle of Wight have an annual rainfall of less than 25 inches (*see* Map, page 95). The copious rainfall on the west coasts of British Columbia, the southern part of South America, and New Zealand is also due to moist westerly winds reaching these shores and the mountains facing them. Australia obtains on the east coast strip and on the slopes of the Dividing Range near this coast an abundant rainfall from the south-east trade winds, while in the interior we have a dry desert. Other east-facing coasts in the trade-wind belts get an abundant rainfall. Mountain ranges lying across the path

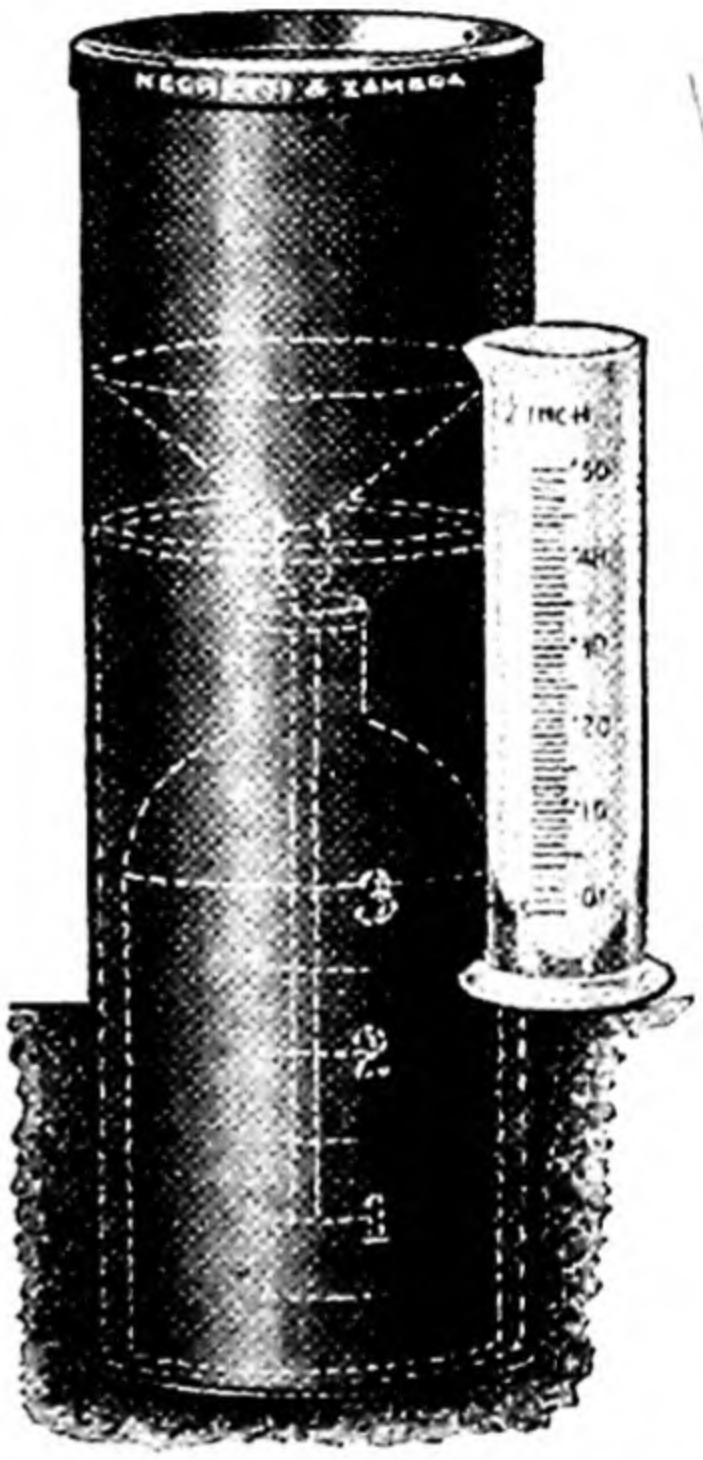


FIG. 32.—RAIN-GAUGE AND MEASURING GLASS. (*See* Glossary.)

of the trade winds have a heavy rainfall. This is well seen in the eastern part of Brazil, especially on the eastern slopes of the high Andes, this abundant rainfall feeding the Amazon and its many tributaries (*see* Map 3).

These high mountains, in fact, cause so much ascension and cooling of the winds that all the moisture is taken out of the air before it passes to the other side, so that in Peru there is an almost rainless district. The higher the mountains that meet warm moist winds the more complete is the removal of the moisture on the weather side, and the drier is the land on the lee side. Mountain ranges that run nearly parallel with the winds have no well-marked wet and dry sides. It follows from the above that the average rainfall decreases as we pass from coast-lines that meet moist warm winds into the interior of the land. Thus in Europe at about the same latitude we find the following annual rainfalls :—Utrecht, 27·5 inches ; Berlin, 22·8 inches ; Drenburg (in Poland), 14·1 inches. (*See* Question 185.)

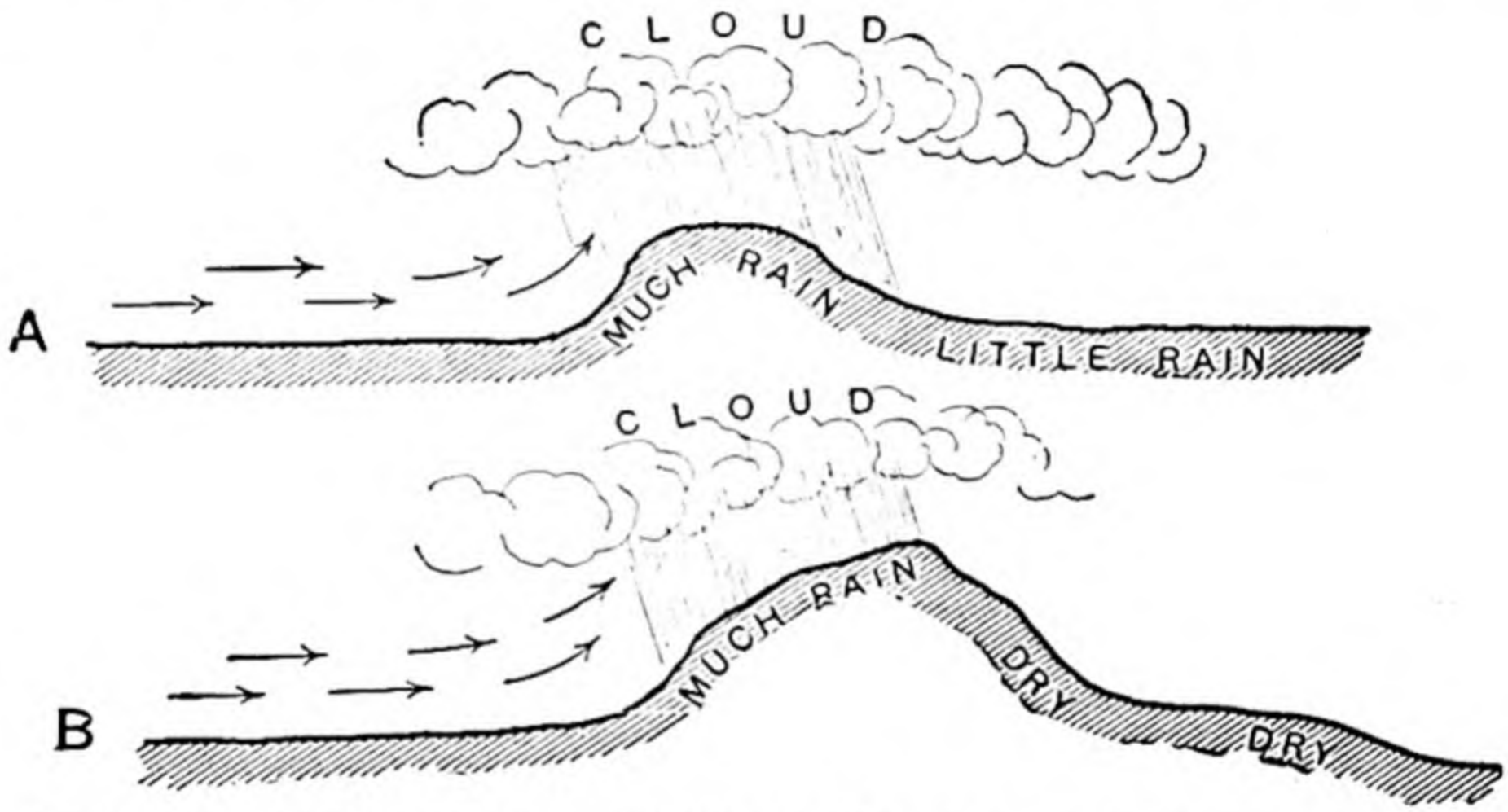
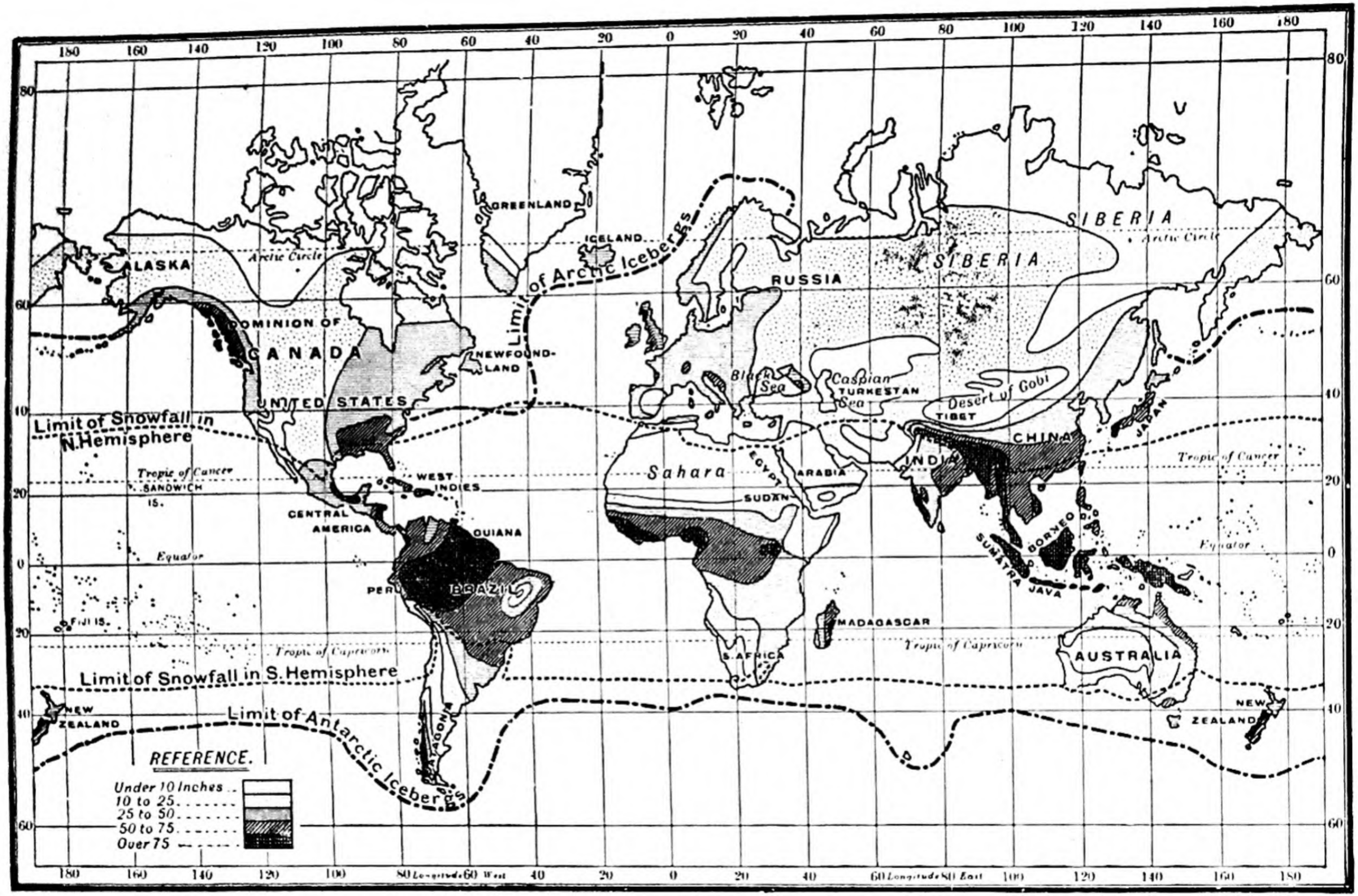


FIG. 33.—MOIST WINDS MEETING HILLS A, AND HIGH MOUNTAINS B, LYING ACROSS THEIR PATH.

The exceptionally heavy rainfall on the southern slopes of the Himalayas and the arid conditions of the desert of Gobi are explained in the next paragraph. Some small regions of heavy rainfall (above 75 or 80 inches) are too small to be shown on the general map. In the tropics a rainfall below 20 inches is not sufficient for agriculture, and one below 10 inches leads to desert conditions. In temperate lands half these amounts suffice. Within the polar circles the rainfall (including snow) is very small, for the cold air can hold but little water-vapour, even when saturated (*see* Glossary, ' Humidity ').

The rainfall of a district is not only determined by the nature of the prevailing winds, but in the same district **rainfall increases with elevation above the sea-level,** up to a certain limit. The ascending currents of air pass into regions of lower pressure the higher they rise, and consequently expand. Expansion leads to a lowering of temperature—*dynamical cooling*, as cooling by expansion is called—and this cooling the air diminishes its capacity to hold water-vapour, so that condensation takes place in the form of cloud and rain. Thus the



MAP 3.—DISTRIBUTION OF MEAN ANNUAL RAINFALL.

annual rainfall at Whitehaven, on the Cumberland coast, is 43½ inches, but at Loweswater, 336 feet high, in the Cumberland hills, the fall is 67 inches; while the rainfall on the summit of Ben Nevis is 52 inches more than at the foot of the mountain.

29. **Regions of Great Rainfall and Great Drought.**—Special geographical conditions operating with the chief causes of rainfall give rise to regions of excessive rainfall. The regions of greatest rainfall are (1) parts of the equatorial regions of calms already mentioned; (2) certain districts where warm moisture-laden winds meet high hills, are forced to ascend, and are thus cooled below their dew-point.

One of the heaviest recorded rainfalls occurs on the Khasi Hills in Assam, at an elevation of 4,440 feet, where a rainfall of 464 inches as the mean of thirty-three years has been registered. This high

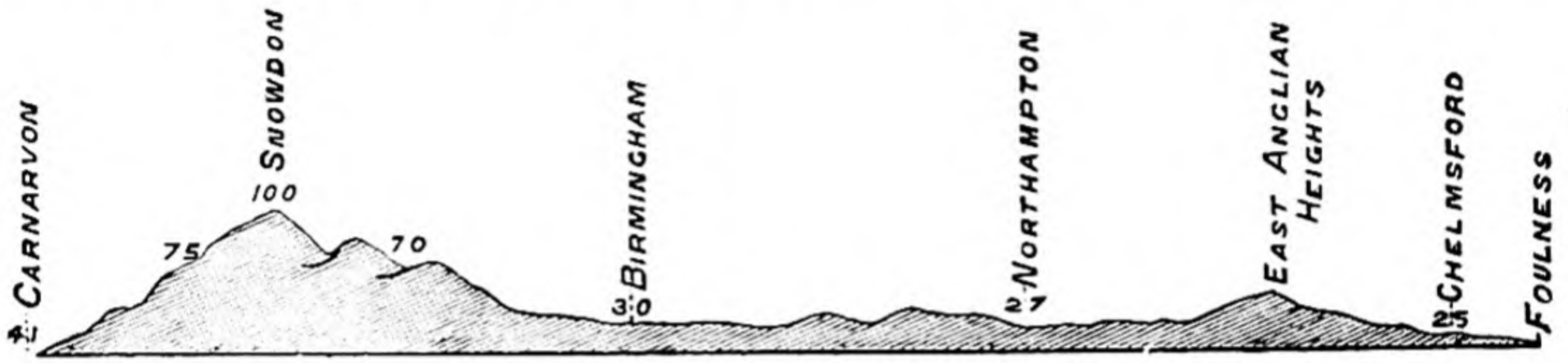


FIG. 34.—SECTION ACROSS ENGLAND FROM CARNARVON TO ESSEX, SHOWING VARIATION OF RAINFALL, WITH HEIGHT, AND DISTANCE FROM THE WEST COAST.

rainfall is due to the south-west monsoons, moisture-laden warm winds that blow from the Bay of Bengal and are here deflected abruptly to a great height. The south-west monsoon blows only from April to September, but during the winter months, when the north-east monsoon prevails, scarcely any rainfall is recorded. At Mahabaleshwar, on the Western Ghats, similar conditions prevail, for it is at nearly the same height, close to the sea-coast, and receives the south-west monsoon during the summer months from the Indian Ocean.

Greytown, in Nicaragua, with a rainfall of 260 inches; Valdivia, in Southern Chili, with a rainfall of 116 inches; and Hokitika, on the west coast of New Zealand, with a rainfall of 112 inches, are other examples of high rainfall in positions bringing them into early contact with winds from the sea charged with a high percentage of water-vapour.

Regions of very small rainfall and practically rainless regions are either regions in which the winds are coming from a higher and cooler latitude or regions that are situated far inland on the leeward side of mountains and high hills. Thus a part of the Sahara to the north of latitude 18° N., Egypt, and a part of Arabia are almost rainless deserts, as the prevailing winds come from the north, and, passing into a warmer district, have their capacity for moisture increased. Even on the open ocean, in the trade-wind belt, little or no rain falls, as these winds come from higher latitudes. On the other hand, the interior of Australia, the elevated plateau of Tibet, a district in Peru, a part of the great Salt Lake region and the elevated plateau owe their dryness to the fact that the winds that reach them have already been robbed of their moisture. The arid desert of Gobi is not only shut off by the lofty Himalayas and the Kuen Lun range from receiving,

any of the rain so abundantly brought to their slopes, but the north-east winds from Siberia are too cold to allow of any being brought by them (*see* Map 3).

30. **Snow and Hail.**—Snow consists of aqueous vapour frozen into spicules of ice crossing at an angle of 60 degrees. Hence snow crystals usually consist of six rays arranged about a centre, or of hexagonal plates, though other forms are also found. A number of crystals hanging together form a snowflake. Snow does not fall on all parts of the earth at sea-level, for, even if formed in the higher regions of the atmosphere, it would melt before reaching the sea-level in the tropics. Yet, as the temperature decreases with increasing height, it is found at certain elevations in all regions. Thus the high peaks of the Andes near the equator are continually covered with snow. **The snow-line, or limit of perpetual snow, is that line below which the heat of summer is sufficient to melt all the snow that falls, and above which more snow falls than the heat of summer can melt.** It is the height at which the average air temperature is 32° F. or less. This line takes the form of a curve starting at a height of about 16,000 feet at the equator, and descending to the sea-level near the poles. In the Alps it is between 8,000 feet and 9,000 feet; in Britain, a little over 4,000 feet; at the North Cape, only 2,000 feet; in Spitzbergen, near the sea-level.[1] **Sleet** is a mixture of melting snow and rain. **Hail** is formed of balls of ice particles. In some cases these appear to be carried upwards several times into colder regions of air, where they get several coats of ice, and then fall as true hailstones, in some cases as large as a hen's egg.

CHAPTER IV

THE SEA

31. Our earth may be regarded as an irregular globular mass of various rocks, the deeper valleys of its surface being covered with the salt water which we call the sea. The sea covers nearly three-fourths of the earth's surface, 140,000,000 sq. miles out of a total surface of 197,000,000 sq. miles. The various land masses break up the sea into parts which have special names, the largest expanses of water being called **oceans.** These are :—

(1) The Atlantic Ocean, lying between the western shores of the Old World and the eastern shores of America, and stretching from the Arctic Circle in the north to the Antarctic Circle. Its shores are much indented, and it contains many more or less enclosed areas, termed **seas**—*e.g.*, the Mediterranean, the

[1] The height of the snow-line does not depend entirely on latitude, but varies with the prevailing winds and the greater or less volume of snow that falls. Thus, on the moister though warmer southern slope of the Himalayas, where much snow falls, it is about 16,000 feet, while on the dry northern slope the snow-line is nearly 20,000 feet high.

Baltic, the White, Hudson Bay, &c. Its total area is about 32,000,000 sq. miles. More than half the land of the world sends rivers into the Atlantic and its seas.

(2) The Pacific Ocean, lying between the west coast of America and the east coast of Asia and Australia. The

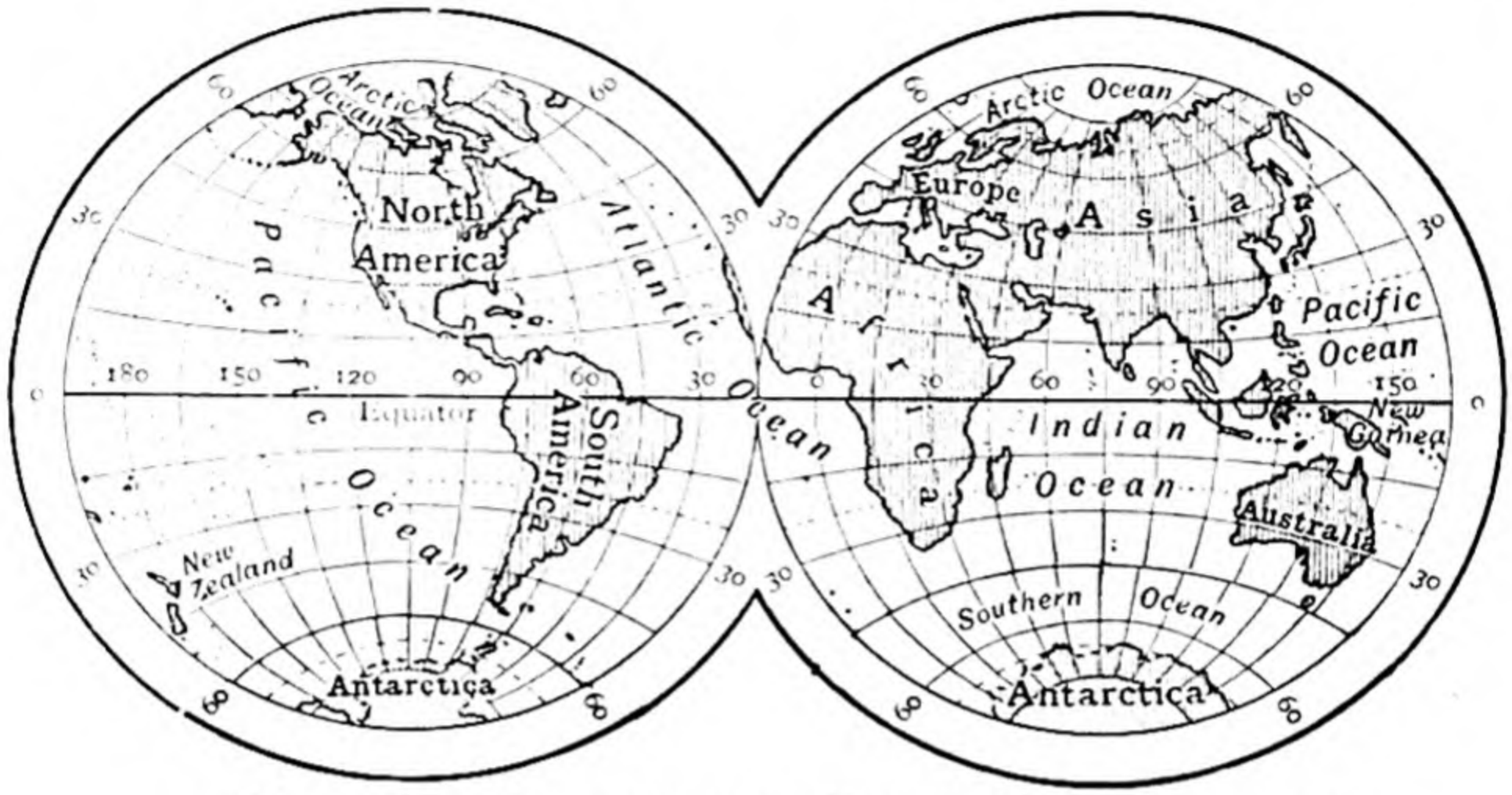


FIG. 35.—WESTERN AND EASTERN HEMISPHERES.

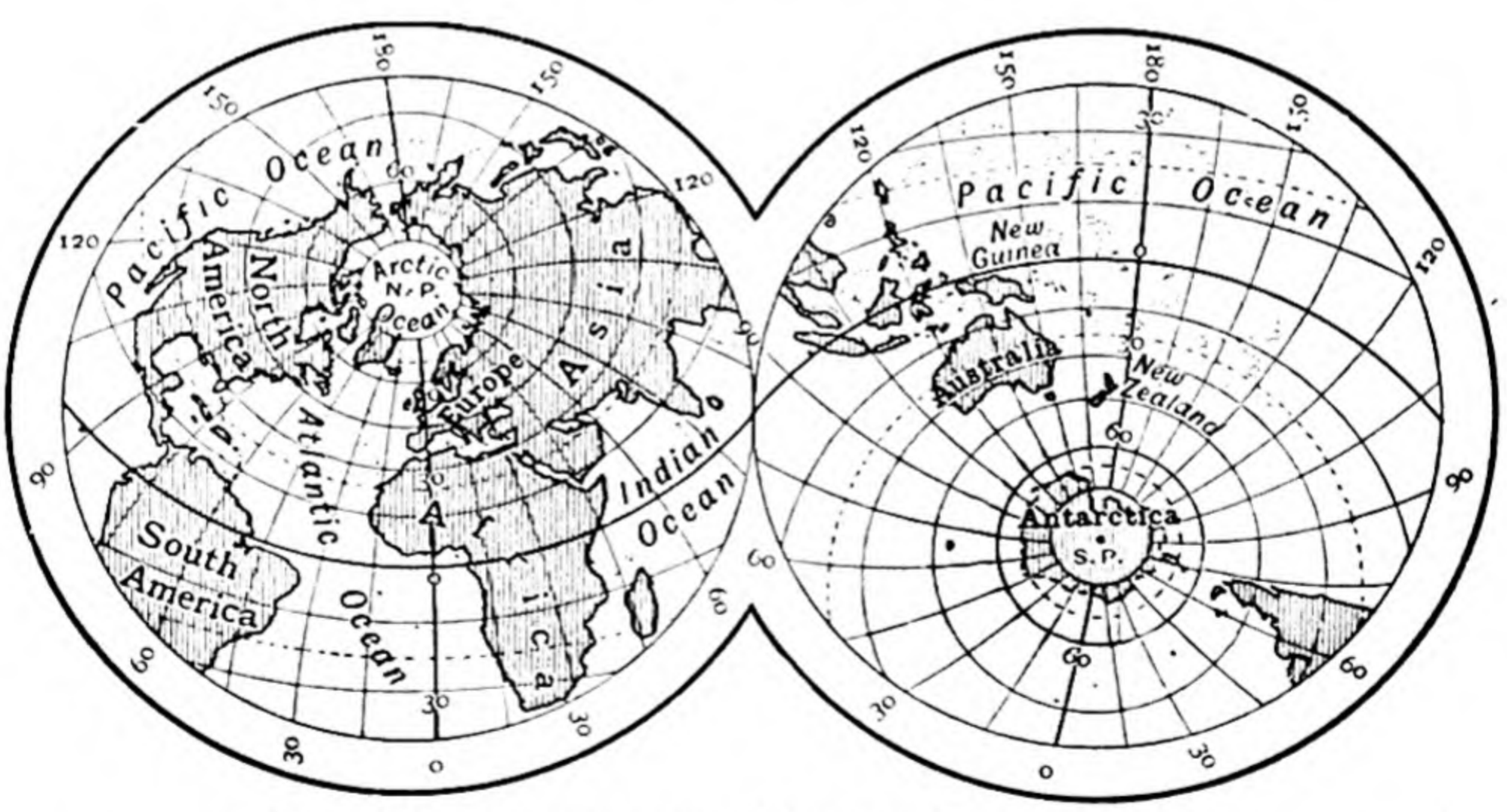


FIG. 36.—LAND AND WATER HEMISPHERES.

Pacific is the largest ocean, having an area of about 55,000,000 sq. miles, a length from Behring Strait to the Antarctic Circle of 9,000 miles, and a greatest breadth along the equator of 10,000 miles. The Pacific differs from the Atlantic not only in being much larger, but by being more thickly dotted with islands, by receiving fewer large rivers, and by having fewer

branches. Its chief seas are the Yellow Sea, Sea of Okhotsk, Japan Sea, Celebes, and Sulu Seas.

(3) The Indian Ocean, lying between the south of Asia and the Southern Ocean. It has an area of about 17,000,000 sq. miles, and its chief seas are the Red Sea, the Arabian Sea, and the large Bay of Bengal.

(4) The Arctic Ocean, lying within the Arctic Circle.

(5) The Southern Ocean, lying around the Antarctic Continent, a great unbroken expanse of water stretching between 40° S. latitude and the region of Antarctic ice.

A plane passing through the two poles of the earth and the middle of the Atlantic on one side, and through the Pacific Ocean on the other, divides our globe into two hemispheres. We call the half which lies to the west of England the Western Hemisphere, and the other half the Eastern Hemisphere. The student should learn the continents in each of these hemispheres, and note the proportion of land and water in each, as well as the fact that all the great land masses are widest in the north and taper towards the south.

If we divide the globe into two halves by a plane passing through the equator we get a Northern Hemisphere and a Southern Hemisphere, and see that there is nearly three times as much land north of the equator as there is south of it. In fact, 42 per cent. of the surface is land in the northern hemisphere.

Again, we may suppose the globe divided into two hemispheres so that London may be the centre of one and a point near New Zealand the centre of the other. This makes London the centre of what is called the Land Hemisphere, as 50 per cent. of this hemisphere is land, and the point near New Zealand the centre of what is called the Water Hemisphere, as only 8 per cent. of this hemisphere is land and 92 per cent. water.

32. **Composition of Sea-water.**—Sea-water is not pure water, but contains dissolved in it certain chemical substances termed salts. The salts amount on the average to $3\frac{1}{2}$ grains in 100 grains of water, the most abundant (2·7 per cent.) being chloride of sodium, or common salt. Other salts are magnesium and potassium chlorides, magnesium and calcium sulphates, and calcium carbonate. Variations from the average percentage of salts in solution (3·5) occur in many parts. Seas receiving a large quantity of water, and where there is but little evaporation, such as the Baltic, have a percentage smaller than the average; seas receiving but little

fresh water and with much evaporation, such as the Red Sea, have a greater percentage than the average.

Atmospheric gases are also dissolved in sea-water, the dissolved oxygen being necessary to the life of fishes and other inhabitants of water.

The **source** of the salts contained in sea-water is to be found, to a large extent, in the **fresh** water of rivers that flow into it, for the rivers are continually carrying down small amounts of the same salts dissolved out of the rocks of the land. There is thus a tendency in the sea to become salter, indeed, the age of the earth has been calculated by estimating how long it has taken the sea to become as salt as it is, presuming it was originally fresh. Some salts are used up to some extent by certain animals and plants that live in the sea. The calcium salts are the material out of which the hard parts of shellfish, corals, and of the tiny foraminifera are built up. The slight quantity of silica aids in supplying the hard secretion of certain minute plants termed Diatoms and certain tiny animals termed Radiolaria. On the death of these living beings the hard parts settle to the bottom to form marine deposits (*see* Par. **35**).

Compared with pure water, sea-water is slightly heavier, its mean density or specific gravity being 1·0275, that of pure water being 1. The salter the water is, the greater is its density. Thus the Red Sea, where there is great evaporation and hardly any supply of fresh water, is denser and more salt than the Baltic, where there is little evaporation and an abundant supply of fresh water.

To obtain the salt dissolved in sea-water we need only evaporate the sea-water placed in a basin, and the salt crystals will be left behind.

33. **Floor of the Sea.**—By sounding and dredging much has been learnt regarding the depth of the sea, its temperature, the nature of the bottom, and the life it contains. Around the British Isles the sea is but shallow, seldom reaching 100 fathoms, but, speaking generally, the great oceans sink rapidly from near the coast to a depth of 2 or 3 miles. The bottom then continues as an undulating plain, with here and there deep hollows, while in other places rising into submarine ridges and plateaux. Islands occasionally project beyond the surface.

The northern part of the Atlantic Ocean is for the most part under 1,000 fathoms in depth, but south of 60° N. there are great troughs or hollows with a mean depth of 2,500 fathoms, separated by a ridge of less depth (1,500 fathoms), extending along the middle of the ocean from north to south. This ridge in the middle of the Atlantic is called the **Dolphin Ridge** in the north, the '**Challenger**' **Ridge** in the south, and the **Connecting Ridge** joins the two. One of the deepest recesses in the Atlantic lies to the north of the island of St. Thomas, where the *Challenger* obtained a sounding of nearly 4½ miles.

The Pacific Ocean has a mean depth of about 2,500 fathoms. The floor of the eastern part is fairly level, undulating at a depth of between 2,000 and 3,000 fathoms, while the western side is very irregular, large patches of shallow water being found in some parts and deep depressions in other parts. The American vessel the *Tuscarora* obtained a sounding of 4,655 fathoms, nearly 5½ miles, between the Kurile Islands and the coast of Japan. In a region of the South Pacific south of the Friendly Isles, a depth above 5,000 fathoms (30,000 feet) was obtained by H.M.S. *Penguin* in three soundings. The greatest depth recorded is

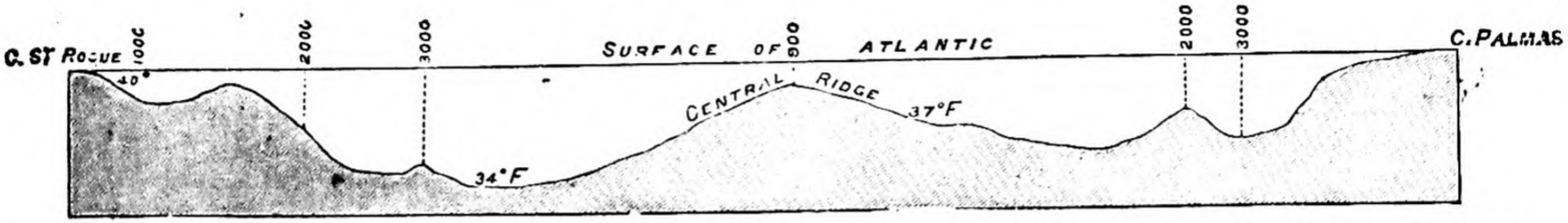


FIG. 37.—SECTION ACROSS THE ATLANTIC BETWEEN CAPE PALMAS IN AFRICA AND CAPE ST. ROQUE IN BRAZIL, SHOWING FORM OF OCEAN FLOOR AND DEPTH IN FATHOMS.

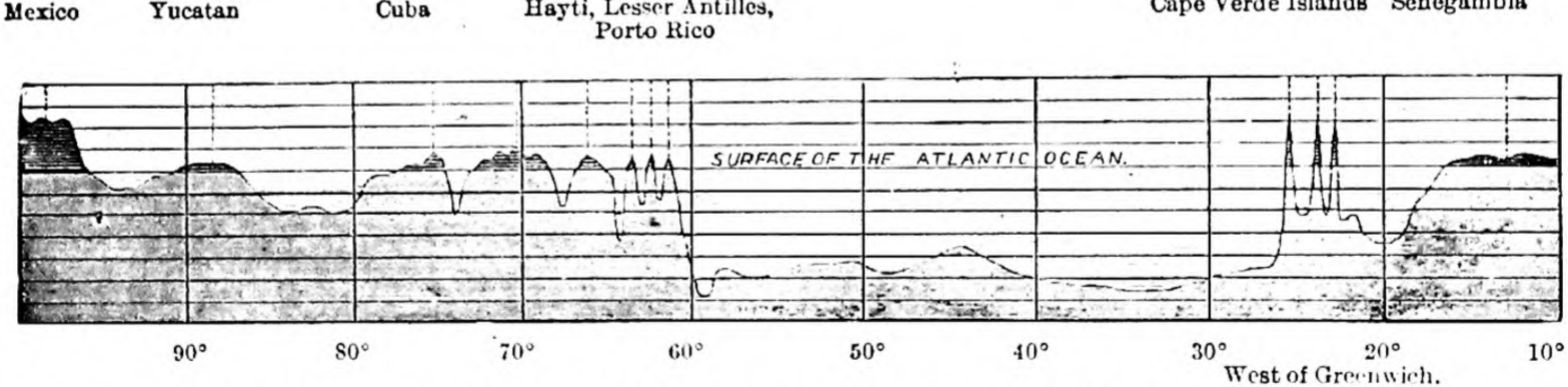


FIG. 38.—SECTION ACROSS THE ATLANTIC OCEAN BETWEEN SENEGAMBIA AND THE TABLELAND OF MEXICO, 7,000 FEET HIGH, SHOWING OCEAN FLOOR. The greatest depth shown is about 17,000 feet. (Contour intervals, 300 feet.)

35,410 feet some 40 miles off the coast of the Philippine Islands, by the German cruiser *Emden* in 1927.

The Arctic Ocean is comparatively shallow, but a tongue-shaped depression exceeding 2,000 fathoms lies between the north of Norway and Greenland.

Figs. 37 and 38 indicate a mode of showing ocean depths, but it must be remembered that the vertical scale is much greater than the horizontal scale.

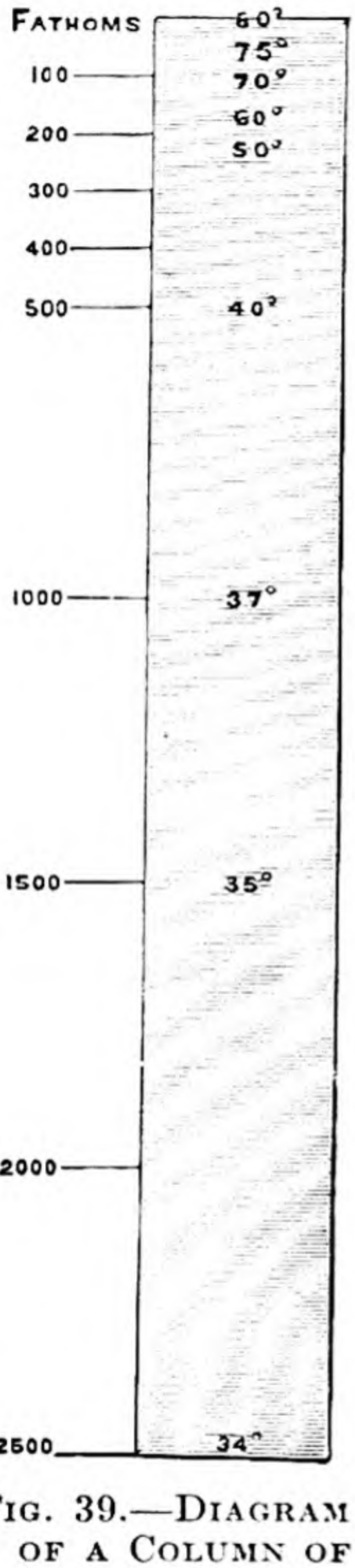


FIG. 39.—DIAGRAM OF A COLUMN OF SEA-WATER NEAR THE EQUATOR, SHOWING THE TEMPERATURE AT VARIOUS DEPTHS. (A fathom equals 6 feet.)

34. **Temperature of the Sea.**—The **temperature** of the **surface** of the sea varies according to the latitude or distance from the equator, and also, except in equatorial regions, according to the season of the year, though the seasonal variation is much smaller than that of the atmosphere. Near the equator the average temperature is about 80° F., and this diminishes as we approach the poles, the water of the northern hemisphere, however, being warmer than that of the southern hemisphere. The highest mean surface temperature is 90° F., in the southern part of the Red Sea. Around Britain the surface temperature of the sea is about 60° in August and 49° in February, a range of 11°, while the range of air temperature is 20° on the west and about 22° on the east. In the deep, open sea of all parts the temperature is only about 35°, a continual decrease from the surface taking place, quickly at first, but more slowly afterwards (*see* fig. 39).

35. **Deposits on the Floor of the Sea.**—In most places the sea, aided by the action of rain and frost, is continually wearing away the coast, and the broken fragments are hurled about by the waves until the angular fragments are reduced to rounded pebbles, sand, or mud. The finer the *débris* becomes the farther is it carried out to sea by the action of tides and currents. In the '*Challenger* Reports' marine deposits are divided into (1) Terrigenous Deposits, or deposits derived from the wasting of the land, and carried down as sediment by the action of rivers, waves, and other movements of water; (2) Pelagic Deposits, or deposits formed and found only in the deeper regions of the ocean basins.

The **terrigenous deposits** consist of (*a*) shore formations, blue mud, green mud and sand, red mud—found in inland seas and along the shores of continents; (*b*) volcanic mud and sand, coral mud and sand—found around oceanic islands and along the shores of some continents. The **pelagic deposits** include Pteropod Ooze, Globigerina Ooze, Diatom Ooze, Radiolarian Ooze, and Red Clay.

The detritus, or waste material produced by the action of the waves, is deposited at no great distance from the shore, and shingle beds are not often met with at a distance of a mile from the coast. The finest particles of all are not carried further than 200 miles from the shore. These fine particles give rise to the **greenish** or **blue muds** so often found at depths of from 100 to 700 fathoms. This blue mud is the most extensive deposit now forming near the great continents and in large inland seas. Where large rivers enter the sea portions of the finest material may be carried to still greater distances. These deposits

FIG. 40.—SECTION OF GRAVESEND CHALK, SHOWING SHELLS OF FORAMINIFERA. Highly magnified.

FIG. 41.—ORGANISMS IN ATLANTIC OOZE, CHIEFLY FORAMINIFERA, WITH A FEW RADIOLARIA AND SPONGE SPICULES. Highly magnified.

now forming near the shores of continents and large islands within 200 miles of the shore, resemble in all respects the sedimentary rocks found in the earth's crust, and may at some distant period form the chalks, sandstones, shales, and conglomerates of future land. In the deeper parts of the ocean very different deposits are found. North of lat. 50° S., at depths varying from 250 to 2,900 fathoms, a fine, light-coloured ooze or silt called **Globigerina**[1] **ooze** is found. It consists chiefly of the minute calcareous shells of Globigerinæ and other Foraminifera, mixed with some siliceous shells of Radiolaria. At greater depths this 'modern chalk of the Atlantic' passes into red clay. In some places the calcareous ooze consists of the thin transparent shells of another class of animals (molluscs), called **Pteropods. Radiolarian ooze** is a deposit met with in the Western and Middle Pacific. It consists of minute perforated siliceous shells, formed by tiny creatures

[1] Globigerinæ are minute organisms living at the ocean surface in countless numbers. As they die their calcareous shells sink to the bottom without being dissolved, except in the deepest parts.

called Radiolaria, that live in all zones, and secrete silica for their skeletons. **Diatom ooze** consists of the siliceous valves of the frustules or cells of diatoms, tiny **plants** that live on the surface, and after death sink to the bottom. These microscopic shell remains are found in areas of great depth far from land. **Red** and **chocolate clays** form the chief deposit at the greatest depths. These are partly of volcanic origin, and are probably produced by the volcanic dust carried by the winds, or from the decomposition of the pumice-stone borne by the waves. The insoluble residue of calcareous organisms also aids in forming these clays. The colour is mainly due to the presence of iron and manganese oxides. Mixed with these clays, especially in the South Pacific, great numbers of sharks' teeth and the hard, compact, ear-bones of whales are brought up by the dredge.

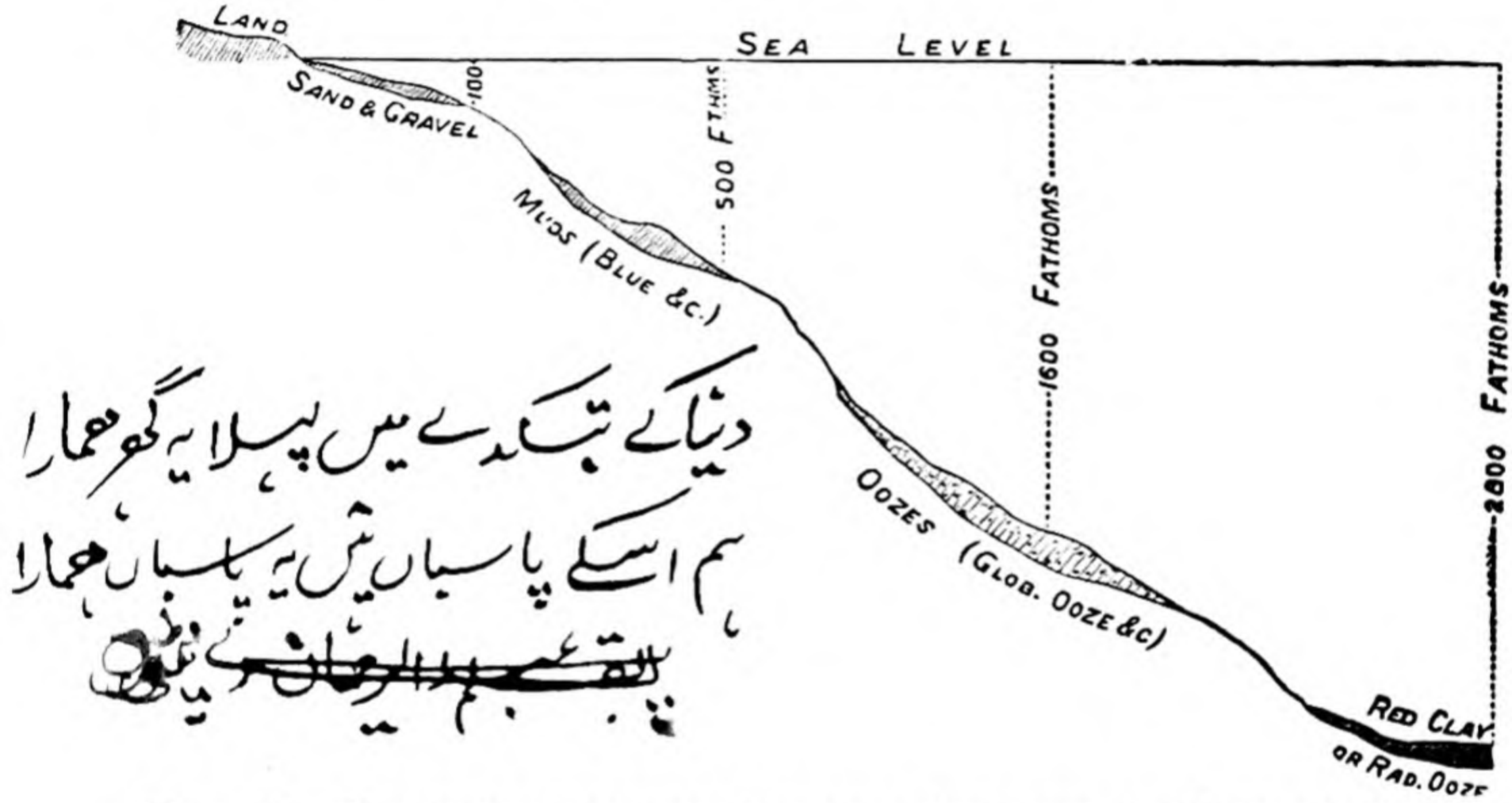


FIG. 42.—DIAGRAM SHOWING OCEANIC DEPOSITS AT VARIOUS DEPTHS.

36. **The Ice of the Sea.**—Sea-water does not freeze until a temperature is reached nearly five degrees below the freezing-point of fresh water, and it is worthy of note that in freezing it throws out much of the salt it contains. The low temperature in Arctic and Antarctic regions causes the sea to be covered with a coat of ice from 2 feet to 10 feet thick every winter, and the short summer leads to the breaking up and partial melting of this ice. The ice often begins as a shelf attached to the shore, and thence spreads over the distant surface. This shelf of ice, termed the **ice-foot,** is often loaded with a mass of boulders and other materials from the overhanging cliffs.

The surface of the frozen sea is usually very uneven, owing to the restless movements of the waves. A great stretch of marine ice, called an **ice-field,** is therefore not a level sheet, but

an irregular expanse, having deep hollows and large mounds called 'hummocks.' When the winter covering breaks up, ice-islands, or **ice-floes,** are formed ; but these are often driven together to form **pack-ice.** It is this pack-ice which so often forms a barrier impassable to ships, even in summer, though at times it may open out into channels through which a bold navigator may steer. But many a good ship has been crushed or lifted bodily upon the ice by a change of wind bringing the ice together again.

All attempts to reach the poles failed, until Peary with an Eskimo and dog sledge reached the North Pole in April 1909. No land was to be seen and a sounding through the thick ice showed a depth of 1,500 fathoms without reaching the bottom. An observer at the North Pole looking around him at the face of the earth can only look southward.

Besides the various forms of *marine* ice just described, other huge masses of ice derived from the glaciers on the *land* of polar regions are met with. These are called ice-mountains or **icebergs.** Nearly the whole surface of Greenland and other polar lands is covered with an

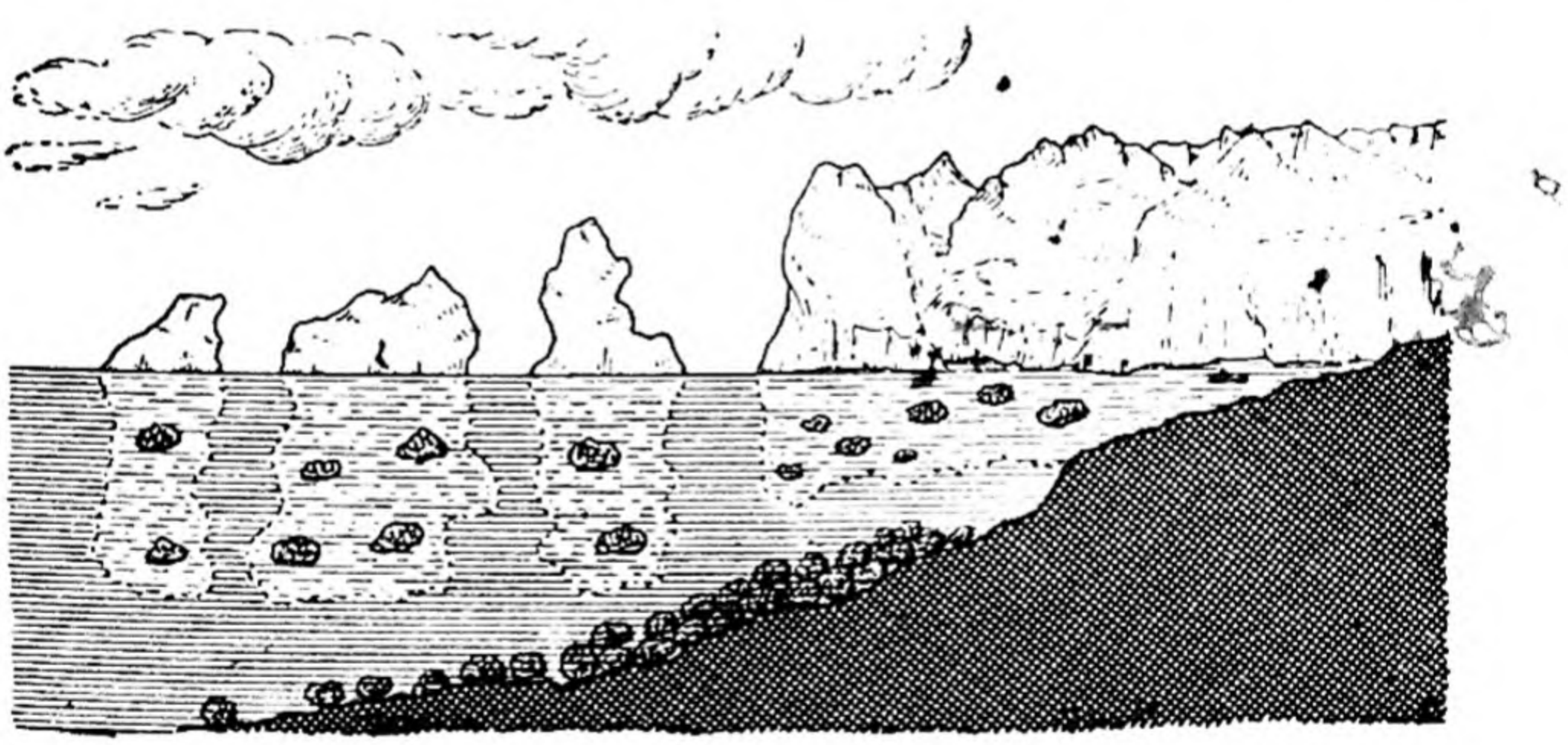


FIG. 43.—DIAGRAM SECTION OF AN ARCTIC GLACIER GIVING OFF ICEBERGS.

ice-sheet that advances slowly towards the sea. Here immense fragments are broken off from the glacier and carried by the waves and currents towards the equator, melting away as they reach the warmer water ; they seldom reach beyond 40° N. See Map 3 for the limit of Arctic icebergs. Icebergs are often of immense size and fantastic shape, and carry boulders and other *débris* derived from the land over which they have passed. Many of the Greenland bergs melt and deposit their loads on the banks of Newfoundland. Ice being but slightly lighter than water, the greater portion—about eight-ninths—of their bulk is below the surface. Chilling the air in their neighbourhood,

they often produce a fog, so that they may not be seen until a vessel closely approaches. These icebergs from Greenland are drifted southwards by the Labrador current and are often a source of danger to ships especially off Newfoundland where fogs are frequent owing to the mingling of the cold air over the Labrador current with the warm air over the Gulf Stream.

In the Antarctic circle around the South Pole there is much glacier-covered land and immense ice-fields. The edge of one of these ice-fields was first seen by Ross in 1839 and has been noted by many mariners since. It forms a great wall of ice known as the Ross Barrier. Two great volcanoes, Erebus and Terror, exist on the Antarctic continent. Antarctic icebergs are mostly flat-topped, and of a deep blue colour. The South Pole, situated on a high plateau, was first reached by a Norwegian explorer, Captain Amundsen, on December 16, 1911. Shortly after, January 18, 1912, Captain Scott reached this pole but he and his four companions perished on the return journey. At the South Pole all around is north. At both poles there is daylight for six months and darkness for six months, and a hundred of such days make a century (Par. 6). The penguin, a sea-fowl with rudimentary wings, is a characteristic bird of the Antarctic regions.

37. **Waves.**—The sea is seldom still, its various movements being classified as **waves, currents,** and **tides.** Any disturbance of the surface of water produces waves, but the chief agent in the case of the sea is

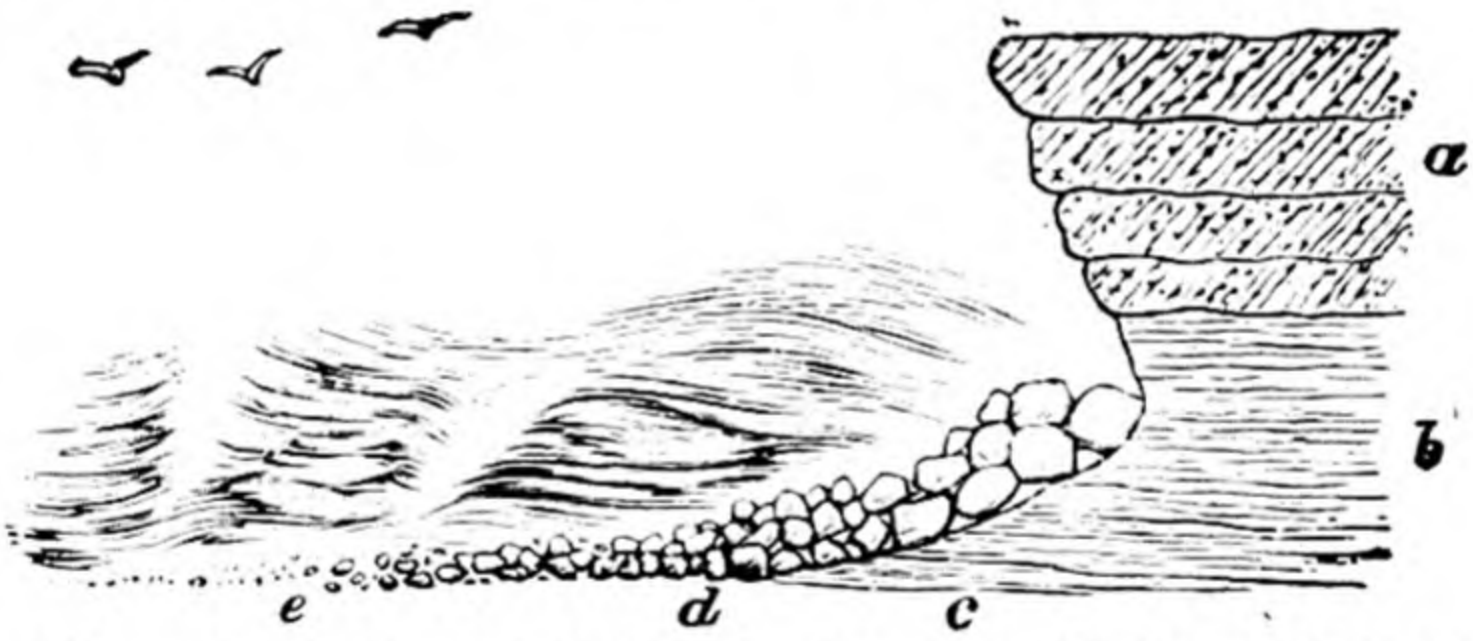
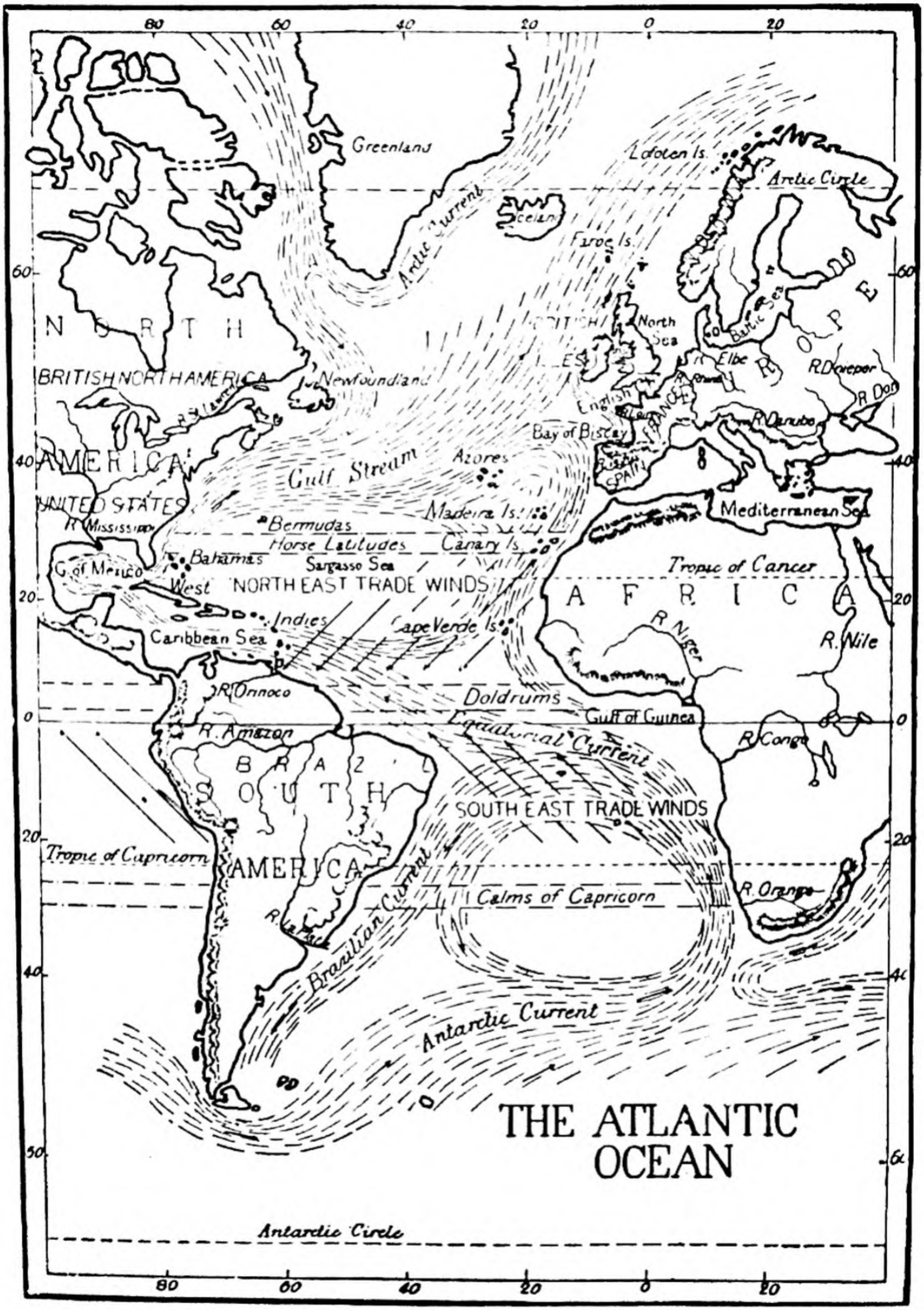


FIG. 44.—ACTION OF THE SEA ON THE ROCKS OF THE COAST.

a, hard rock; *b*, softer rock; *c*, angular blocks; *d*, rounded shingle; *e*, sand.

the wind. These wind-caused waves consist of the alternate rising and falling of water above its ordinary level so as to produce a ridge and a hollow. The top of the wave is the crest, and the depression between two crests is the trough. The distance from one crest to the next, or from one depression to the next, is the **length** of the wave. The chief characteristic of wave motion is, that as the wave passes horizontally onwards over the surface of the sea the water itself simply rises and falls with a slight to-and-fro, rhythmic motion, as may be seen on watching a cork float on the sea. The greatest height of waves, from trough to crest, is about 50 feet, the greatest length about half a mile, and the greatest rate of travel about 80 miles an hour. As waves flow in towards the shelving beach they change in character, the trough becoming flatter and the crest sharper. Many crests curl over, and finally fall as foaming **breakers** near the shore. Waves often produce great changes on a coast by their action, in some places dashing with great force against the rocks and hurling stone against stone, in other places piling


80
60
40
20
0
20
Greenland
Lofoten Is.
Arctic Circle
Arctic Current
Iceland
Faroe Is.
60
NORTH
BRITISH NORTH AMERICA
Newfoundland
North Sea
Baltic Sea
R. Elbe
R. Dniepor
R. Don
English Channel
R. Danube
Bay of Biscay
AMERICA
40
Gulf Stream
Azores
SPAIN
UNITED STATES
Mediterranean Sea
Madeira Is.
R. Mississippi
Bermudas
Horse Latitudes
Canary Is.
Bahamas
Sargasso Sea
Tropic of Cancer
G. of Mexico
West
NORTH EAST TRADE WINDS
20
AFRICA
Indies
Cape Verde Is.
R. Niger
R. Nile
Caribbean Sea
R. Orinoco
Doldrums
Gulf of Guinea
0
Equatorial Current
R. Amazon
R. Congo
BRAZIL
SOUTH
SOUTH EAST TRADE WINDS
20
Tropic of Capricorn
AMERICA
R. Orange
Calms of Capricorn
R. La Plata
Brazilian Current
40
Antarctic Current
80
0
THE ATLANTIC OCEAN
60
Antarctic Circle
80
60
40
20
0
20

MAP 4.

up the rounded fragments and smaller particles to form a stony beach. Where a softer stratum or bed of rock lies beneath a harder stratum a sea-cave may be worn out, though at last masses of the harder rock fall down. Both hard and soft rock become broken and rounded, the smaller particles being carried farther and farther out to sea.

38. **Currents.**—Stream-like masses of water pass from one region of the ocean to another, and are called currents. Oceanic currents are caused mainly by the direct frictional action of the wind on the surface, but their direction is modified by the barriers of land and the rotation of the earth. The effect of temperature is, no doubt, a further cause, for water is expanded and made specifically lighter by heat, contracted and made heavier bulk for bulk by cold. Hence the warm surface water of the tropics will tend to flow towards the poles, while under-currents of colder water will flow towards the equator. That the chief cause, however, of the surface currents is the wind appears from the correspondence between the chief surface currents and the chief periodical winds, the direction of the currents in the Indian Ocean changing with the monsoons. Actual experiments made by Mr. Clayden support this view. He constructed a model of the Atlantic, and, on imitating the action of the winds by air currents blown from a number of tubes, he produced a system of tiny currents corresponding to the real ones. The effect of the earth's rotation on its axis from west to east is that, in whatever direction the water or air moves on the surface of the earth, it is deflected to the *right* [1] in the northern hemisphere, but to the *left* in the southern.

39. **Currents of the Atlantic—The Gulf Stream.**—The N.E. and S.E. trade-winds cause drifts of water, called Equatorial Currents, to pass westward across the middle of the Atlantic from the African to the South American coast. Near Cape St. Roque in Brazil a part of these Equatorial Currents turns southward to form the Brazil current. Another part turns northward and passes along the coast of Guiana in South America.

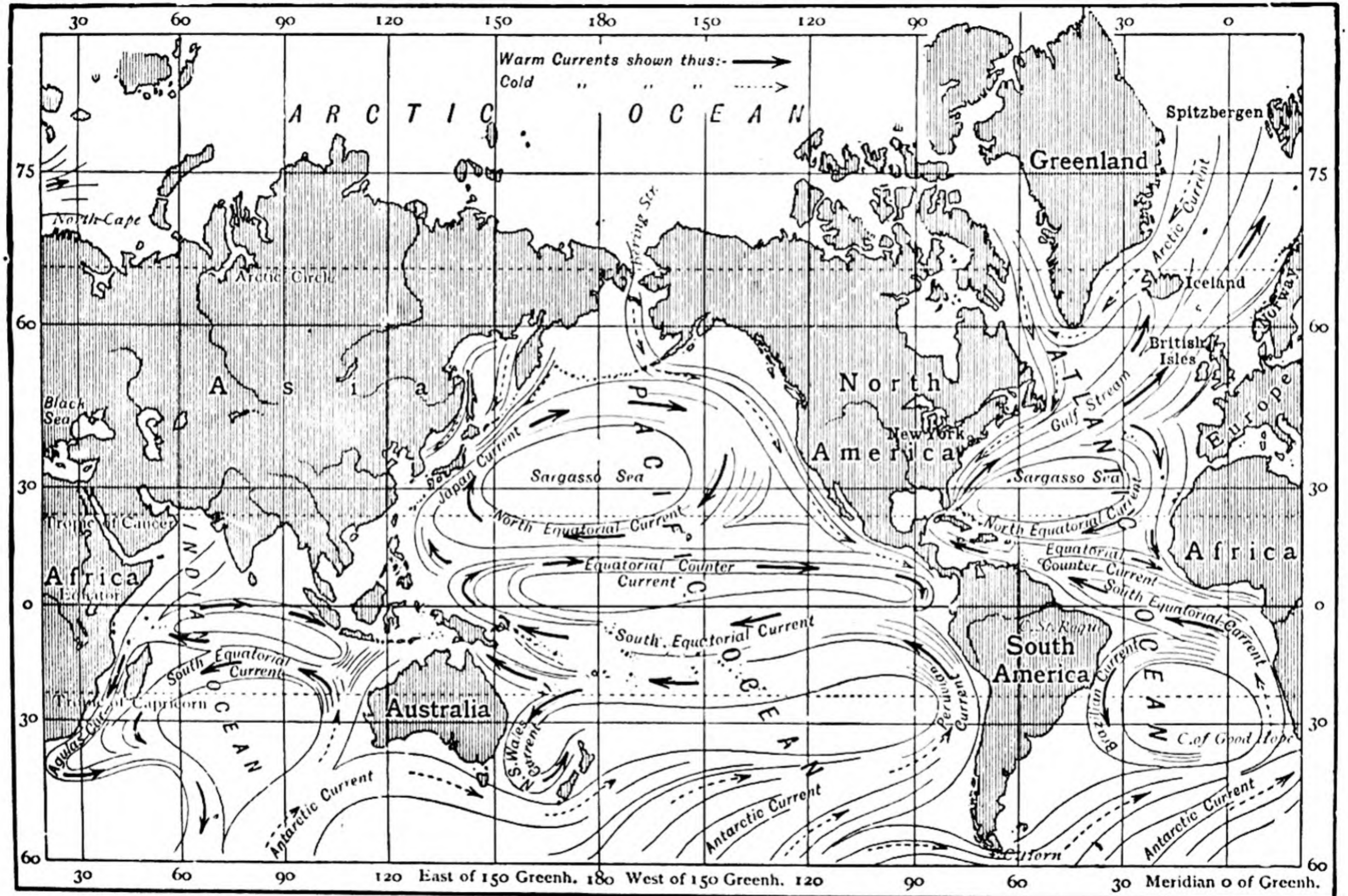
A portion of this branch from the Equatorial Current passes northward outside the West Indian Islands (not shown on Map 4), and another portion enters the Caribbean Sea and thence into the Gulf of Mexico, where the temperature is very high. From the Gulf of Mexico this part flows out between Cuba and Florida as the Gulf Stream. Here it is a strong current about thirty miles wide, with a speed of four miles an hour, a depth of 440 fathoms, a temperature above 80° F., and a

[1] The observer is supposed to be looking in the same direction as the current of air or wind (*see* Glossary, 'Ferrel's Law').

deep-blue colour, due to a high degree of saltness. North of Florida the stream spreads out, loses much of its velocity, becomes shallower and cooler, and turns towards the east, being deflected to the right by the earth's rotation. Off Cape Hatteras about lat. 35° N., it ceases to be a distinct stream, but its warm surface waters, which are here joined by part of the Equatorial Current that passes outside the West Indies, spread out in a great fan, and these waters, urged by the westerly winds of this region, are drifted on across the Atlantic. Near the middle of the Atlantic these drifting warm waters divide. One portion is carried on to the shores of the British Isles, and even farther northwards, so that there is round the British Isles an average surface temperature of the sea of 60° in August and 49° in February. Another portion of the westward drifting warm water of the Atlantic turns southward along the coast of North Africa, thus completing a great oval whirl in the Atlantic. In the midst of this whirl is a vast area with floating sea-weeds called the Sargasso Sea. It should be noted that the Gulf Stream itself does not reach Europe, or even come near it. Its warm drifted surface waters that may be called the Gulf Stream Drift, become merged into the general eastward drift of warm waters near the middle of the Atlantic Ocean. Yet to these warm waters thus brought to our shores, aided by the south-westerly winds that pass over them, we owe in a great degree the comparative mildness of our climate (Par. 60). From the Arctic Sea a cold current flows along the east coast of Greenland, but the important cold current entering the North Atlantic is the Labrador Current that flows southward past the coasts of Labrador and Newfoundland. (Put name in on Map 4.) Off the Banks of Newfoundland, on which mud and stones are dropped by the melting icebergs brought by this current, it meets the northern edge of the Gulf Stream, and there runs along the coast of North America as the **Cold Wall.** Off Cape Hatteras the cold current sinks beneath the Gulf Stream. The meeting of the cold and warm currents off the coast of Newfoundland produces the fogs so common in this region. (See Question 175.)

40. **Currents of the Pacific.—The Kuro-Siwo.**—From the Antarctic Ocean a cold current passes in a north-east direction to South America to form the Chile or Peru current. It is strengthened by the upwelling of cold water and it turns westward about 20° S. lat., and merges into the great equatorial current of the Pacific. This last-named current, formed of a northern and southern part like the equatorial current of the Atlantic, occupies the entire width of the Torrid Zone, and is driven westwards by the trade winds to the East Indian islands. Here it is broken up into several parts, one of which passes into the Indian Ocean, while another turns southwards and carries warm water past Eastern Australia and New Zealand. The main branch, however, turns north past the Philippine Islands, and then, flowing north-east, becomes the great Kuro-Siwo, or Japanese Current. The Kuro-Siwo is thus formed in a similar manner to the Gulf Stream, and resembles it in course and character. Its warm waters sweep along the eastern shores of Asia, and, after passing Japan, it divides into several branches. One of these reaches British Columbia, whose winter temperature is thus raised, just as the drift of the Gulf Stream aids in raising that of the British Isles and North-west Europe. The effects of currents on climate are set forth in Par. 60.

41. **Currents of the Indian Ocean.**—In the Indian Ocean a cool West Australian current unites with a current that comes between Australia



Longmans & Co. London, New York, & Bombay.

Walker & Boutall sc.

Map 5.

and Java to form a south equatorial current that flows west to the coast of Madagascar. A portion of this passes along the east of South Africa as the Agulhas Current. In winter, when the north-east monsoon is blowing, a north equatorial current flows westward from Sumatra, curving upwards in the Bay of Bengal, and then passing to North-east Africa, where it is turned southward. At this time also a counter equatorial current flows eastward from Zanzibar towards Java between the other two equatorial currents. In summer, during the south-west monsoon, the currents of the northern part of the Indian Ocean are reversed.

42. **Tides.**—The tides consist of the alternate rise and fall of the waters of the ocean twice in the course of an interval of nearly twenty-five hours. The rise is called **flood,** the fall, **ebb.** This interval of time corresponds to the interval of time between two successive passages of the moon across the meridian of any place on the earth. Hence it was soon found that there must be some connection between the daily motion of the moon and the ebb and flow of the tides. The force of **gravitation** (*see* Glossary) helps in explaining this connection, for the tides are mainly caused by the difference between the attractive force exerted by the moon on the solid earth and on the more easily moved water.

It is the moon (and to a less extent the sun) trying to draw the waters of the ocean towards itself which causes the tides. The moon's pull at any place will be greatest when the moon is directly over that place *i.e.* when it is on the meridian. Have you ever tried to pull a heavy cart which is standing still ? You know that you pull hard before it begins to move, but once it begins to move it is not such hard work. In the same way the moon has to pull hard before the water begins to move, and so high tide—the result of the moon's pull—occurs a little time *after* the moon is on the meridian.

It used to be thought that this was the only, or at least the principal, cause of the *tides.* But we now know there is another very important cause. When a body is rotating on its axis, loose objects tend to fly away from the surface. In other words, a 'centrifugal force' is set up by the rotation of the earth. But the moon is, at the same time, revolving round the earth, and so the real cause of the tides may be said to be the centrifugal force set up by the rotation of the earth and moon round their common centre, which is not the same as the centre of the earth. You know that the moon rises about three-quarters of an hour later every day, and so the high tide on one day is about three-quarters of an hour later than the corresponding tide on the day before ;

as there are two tides per day, each tide is just over twenty minutes later than the one before.

Fig. 45 shows diagrammatically what *might* happen if there were no land masses on the surface of the earth, but only a

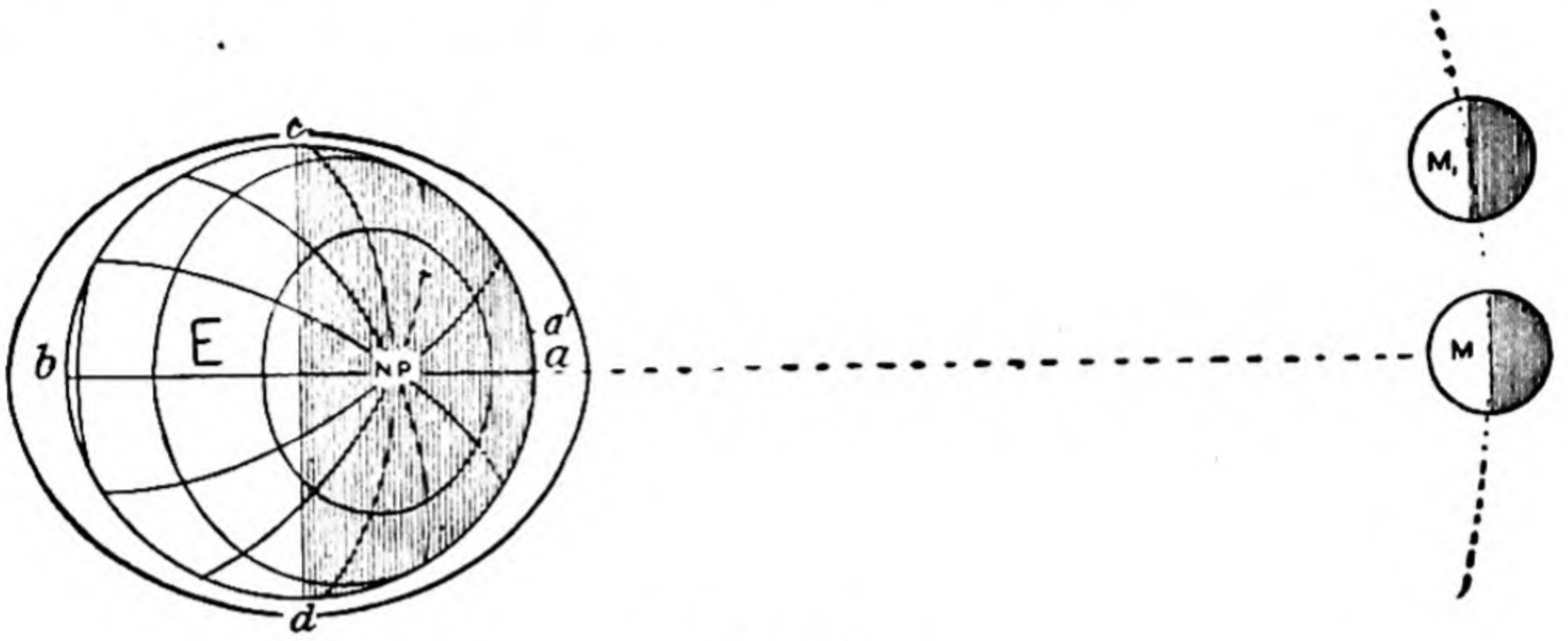


FIG. 45.

continuous ocean of uniform depth. There would be high tide on one side of the earth at *a*, and as the moon moved round the earth the position of high tide would move to *a'*. At the same time there would be low tide at *c*. But actually the position is quite different, because the great land masses

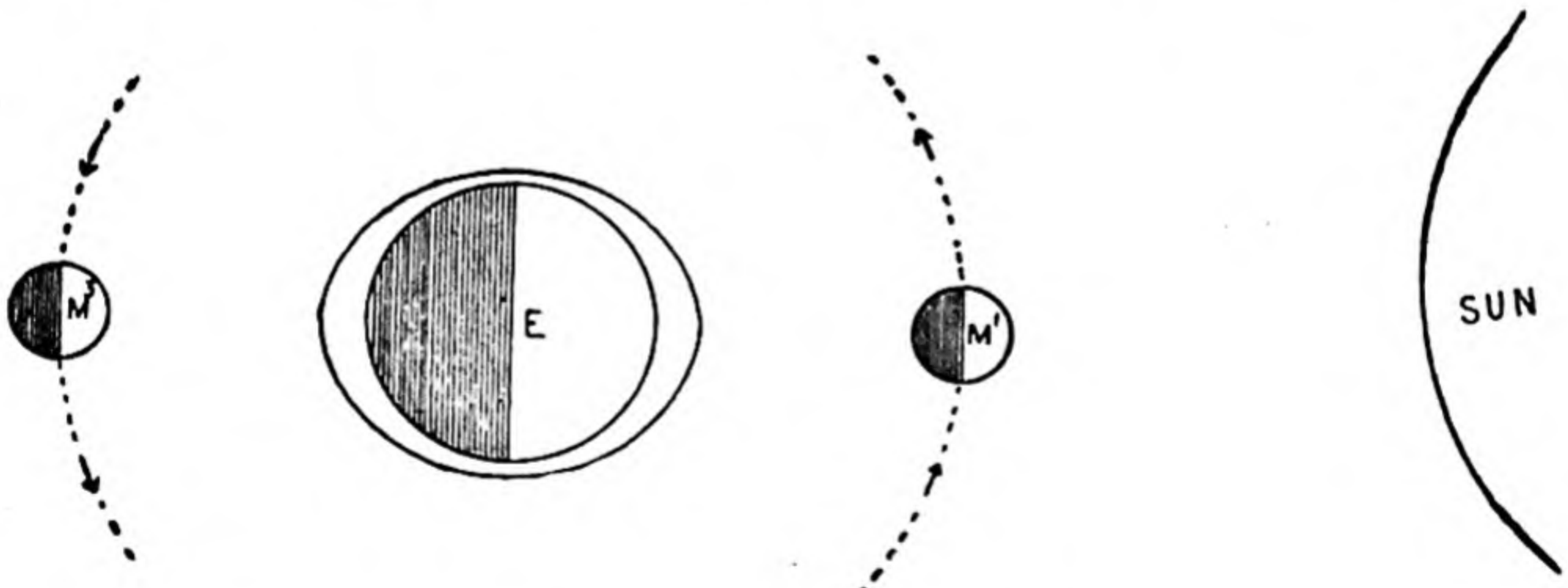


FIG. 46.—SPRING TIDES.

or continents divide the world ocean into a number of ocean basins largely cut off from one another. You all know what happens when you try to carry a shallow basin nearly full of water. In the centre it remains almost steady, but it tends to 'slop up and down' round the sides—first to one side and then to the other. That is roughly what happens in each of the oceans. In the open ocean the water is com-

paratively steady and rises or falls only a few inches or at the most a few feet. But on the margins of the oceans and especially where there is a shallow continental shelf around the continents the effect of the tide is much greater.

The sun is a tide-producing body as well as the moon, but owing to its very great distance from the earth (92,500,000 miles) compared with that of the moon (238,000 miles), its tide-producing force is only about two-fifths that of the moon. At new moon (M^1, fig. 46), or at full moon (M^3), sun and moon are in a line with the earth, and, the two bodies uniting their forces, we have higher tides than usual, called **spring tides,**

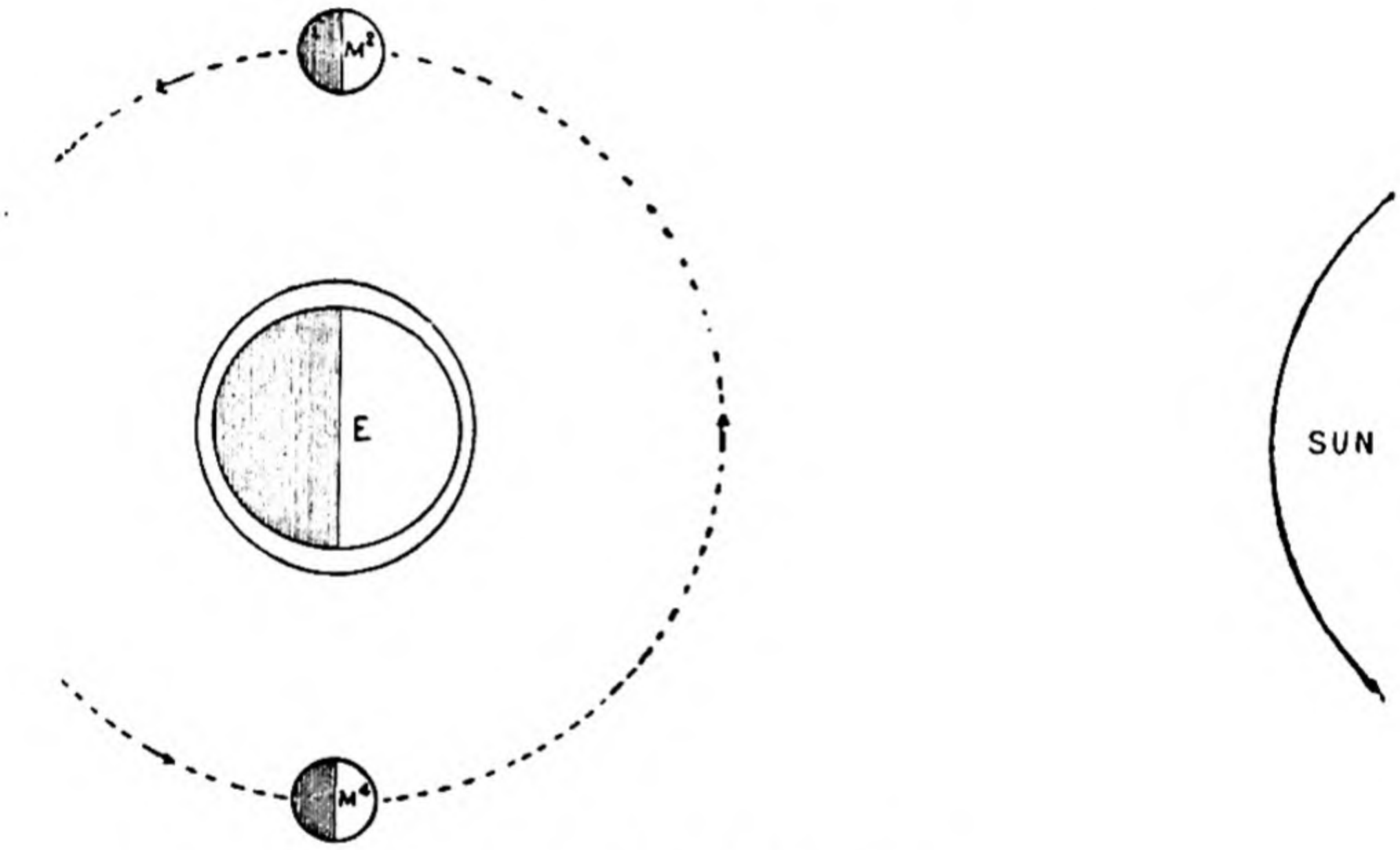


FIG. 47.—NEAP TIDES.

ebb and flow being both greater than the average. Spring tides thus occur at fortnightly intervals. Midway between new and full moon (M^2, fig. 47), when the moon is said to be in her first quarter, and also at the third quarter (M^4), ebb and flow are less than the average, and we have **neap tides,** for the sun's action is then diminishing the greater action of the moon. The highest spring tide of any month is about 1½ days after a new or full moon; the lowest neap tide, about the same length of time after the first and last quarter. Some spring tides are higher than others, because, the moon's orbit being somewhat elliptical, a spring tide that happens when the moon is nearest the earth will be higher than usual. If

such a spring tide occurs not only when the moon is nearest the earth, but when the sun is also nearest—*i.e.* in perigee—the greatest effect of all is produced. (*See* Question 44.)

The average height of the tidal wave in the open ocean is small, but is of varying height round coasts. In a river with a funnel-shaped mouth, and subject to high tides, the spring flood-tide forces a large quantity of water up the river, and a watery ridge stretching across the estuary, termed a **bore** or **eagre**, rushes up the river and raises a very high tide (Fig. 114). This ridge, or bore, is often several feet high. Such a wave, or bore, occurs on the Severn, and has been known to produce on its tributary, the Wye, at Chepstow, a tide 47 feet above low-water mark. On the Hooghly branch of the Ganges the bore travels 70 miles in 4 hours, and passes onwards as a wall of water 7 feet high. The Bay of Fundy has exceptionally high tides, due to the same cause, and the fact that two tidal waves meet at its mouth. On the other hand, the Mediterranean Sea, owing to its narrow connection with the Atlantic, has scarcely any tide. A tidal current rushing through a narrow channel gives rise to a **race**, as the Race of Alderney, or, if the channel be irregular, to violent eddies or whirlpools, like that of the Maëlstrom, near the south end of the Lofoten group of islands.

43. **Lakes** are bodies of water occupying hollows of the land. They have been produced in various ways. Sometimes a landslip or lava-stream has made an obstruction in a river valley, sometimes a plain has slowly subsided or one end of a river valley has been lifted up, and sometimes a hollow has been scooped out by glacier action, or formed by the accumulation of the detritus of an extinct glacier. Small lakes also exist in the craters of some extinct volcanoes, while the Caspian Sea is thought to have once formed a part of the main sea, and to have been shut off by an elevation of the land. The Caspian Sea is a salt lake (6 per cent.), and the largest in the world, Lake Superior, a fresh-water lake, coming next. The highest lakes are Aska[illegible]Chin, in Tibet (16,600 feet), and Titicaca, in the Bolivian Andes (12,[illegible]0 feet). The lowest lake is the Dead Sea, which is 1,290 feet below the sea-level. The Dead Sea, Elton Lake (a small lake north-west of Astrakhan, in Russia), and the Great Salt Lake of Utah, in the United States, contain the largest percentage of salt (25 per cent. for the first two, and 22 per cent. for the last). The salt of these lakes is great on account of the evaporation of the supplying river-water, which has been going on for ages. Lake Baikal, in Siberia, a mountain lake 1,360 feet above the sea, is the deepest lake, its mean depth being 850 feet, and its greatest depth 4,000 feet.

Fresh-water lakes have an outflowing river, and serve as filters or collectors of the sediment brought by the inflowing stream. They also regulate the flow of the outflowing stream by checking floods, and by keeping up a flow in times of drought. Most salt lakes have no visible outlet, the water disappearing by evaporation, and probably, to some extent, by subterranean channels in a few cases. (It must be remembered that fresh-water lakes, like rivers, contain a small quantity of salts in solution, derived from the rocks over

which the water has passed ; but the amount does not exceed, on the average, more than ·02 parts in 100, while sea-water has 3·5 parts in 100. The salts of river-water differ, too, from those of sea-water in the larger proportion of carbonates and silica and the smaller proportion of sodium chloride.)

CHAPTER V

THE LAND

44. **The Continents.**—The land rising above sea-level forms the **continental area,** and amounts to $\frac{5}{16}$ths of the earth's surface.[1] Six great masses of land are usually spoken of as the **continents** of the world, because they are to a large extent distinct masses containing several countries. The continents are :—Europe, Asia, Africa, North America, South America, and Australia. Europe and Asia in reality form but one mass, often termed Eurasia. A southern continent, termed Antarctica, is now known to exist around the South Pole. The following table gives the relative areas, average height, etc., of the continents. Note that Europe has the greatest length of coast-line in proportion to area (1 mile of coast-line to 190 sq. miles), and that Africa has the least amount of coast-line in proportion to area (1 mile of coast-line to 700 sq. miles) :—

—	Area in sq. miles.	Mean height in feet above sea-level.	Length of coast-line in miles.	Population in millions.	Population per sq. mile.
Europe . .	3,760,000	950	19,800	470	126
Asia . .	17,040,000	3,085	35,500	1,045	61
Eurasia .	20,800,000	—	55,300	—	—
Africa . .	11,280,000	2,035	16,100	145	13
North America	7,950,000	2,000	28,100	140	18
South America	6,850,000	2,000	15,600	100	15
America .	14,800,000	—	43,700	—	—
Oceania . .	3,300,000	855	8,800	9	3

The continents are broad towards the north and taper towards the south. Each has an axis or backbone of high land, often a plateau, and serving as a water-parting for rivers

[1] The average height of the land is only about 2,000 feet, while the average depth of the ocean exceeds 12,000 feet.

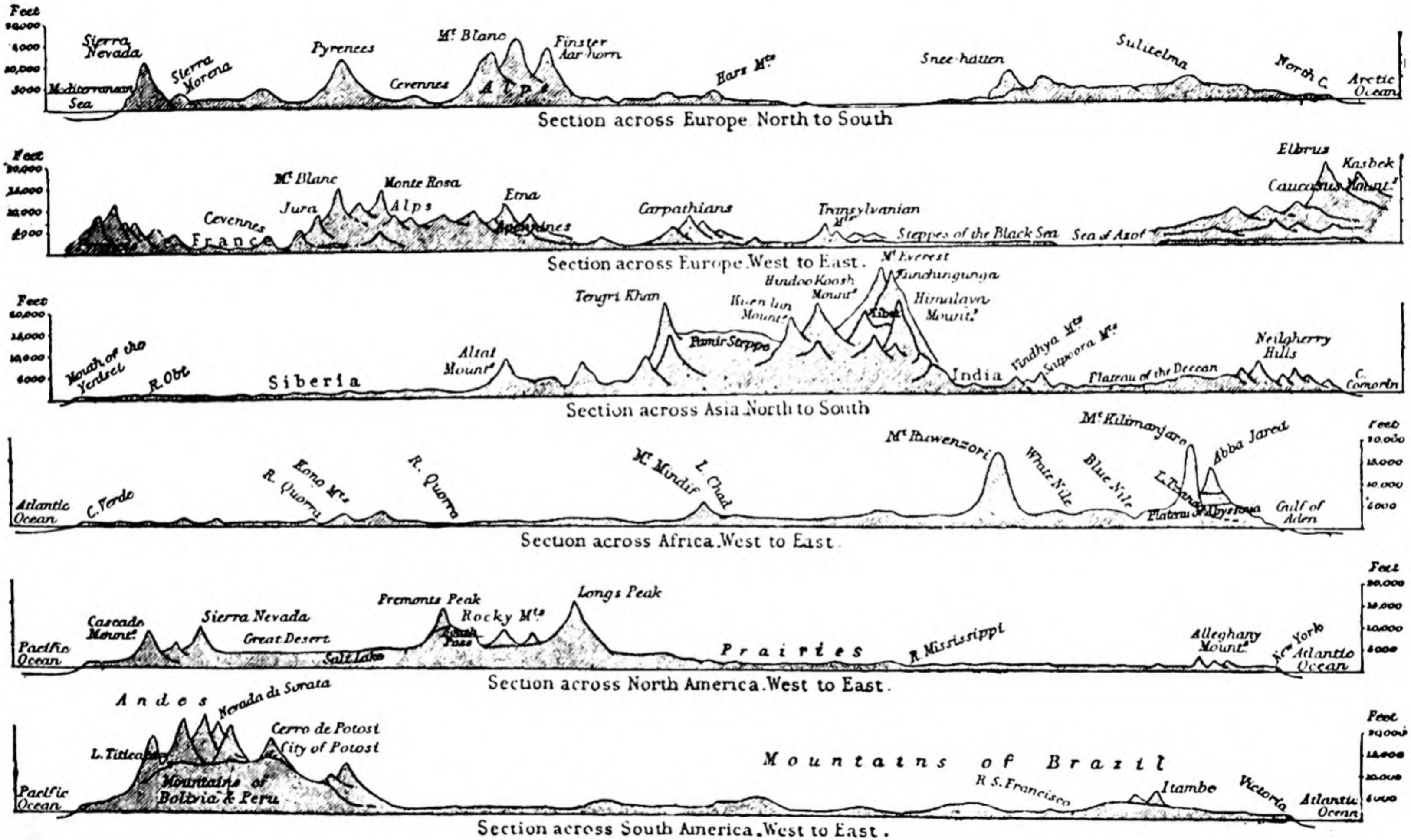

Feet
Sierra Nevada
Sierra Morena
Pyrenees
Mt. Blanc
Finster Aar-horn
Cevennes
Alps
Hars Mts
Snee-hatten
Sulitelma
North C.
Mediterranean Sea
Arctic Ocean
Section across Europe North to South
Mt. Blanc
Monte Rosa
Jura
Alps
Etna
Cevennes
France
Carpathians
Transylvanian Mts
Steppes of the Black Sea
Sea of Azof
Elbrus
Kasbek
Caucasus Mount.
Section across Europe West to East.
Mt Everest
Dunchunginga
Hindoo Koosh Mount.
Himalaya Mount.
Tibet
Tengri Khan
Kuen lun Mount.
Pamir Steppe
Altai Mount.
Siberia
India
Vindhya Mts
Sulpoora Mts
Plateau of the Deccan
Neilgherry Hills
C. Comorin
Mouth of the Yenisei
R. Obi
Section across Asia North to South
Mt Kilimanjaro
Mt Ruwenzori
White Nile
Blue Nile
Abba Jared
L. Chad
Mt Mindif
R. Quorra
Long Mts
R. Quorra
Atlantic Ocean
C. Verde
Gulf of Aden
Section across Africa West to East.
Fremonts Peak
Longs Peak
Rocky Mts
Cascade Mount.
Sierra Nevada
Great Desert
Salt Lake
Prairies
R. Mississippi
Alleghany Mount.
N.Y. Atlantic Ocean
Pacific Ocean
Section across North America West to East.
Andes
Nevada di Sorata
Cerro de Potosi
City of Potosi
L. Titicaca
Mountains of Bolivia & Peru
Mountains of Brazil
R. S. Francisco
Itambe
Victoria
Atlantic Ocean
Pacific Ocean
Section across South America West to East.

FIG. 48.

flowing to all sides. In Eurasia the ridge of high land is situated towards the south, and runs generally east and west, so that the north-flowing rivers are long and have gentle slopes, while the south-flowing streams have a short and rapid course. In North and South America we find a high mountain ridge or plateau on the western side, near the Pacific seaboard, with low ranges near the eastern coast, leaving great central plains, drained by rivers flowing into the Atlantic. Australia has its main highland near the east coast, but Africa is essentially plateau and has two or three chief watersheds in different situations.

The form of the land surface considered in regard to differences of elevation is termed **relief.** One useful way of representing the relief of countries is by supposing a section to be made by a plane perpendicular to the surface. Such sections indicate well the position of highlands, slopes, and plains, but it must be carefully noted that the vertical scale must be represented on a much larger scale than the horizontal, in order to get a useful section within the compass of a page.

In the diagram sections (fig. 48), as in maps coloured or shaded according to elevation, it is easy to see how the axis of high land runs through the great continents and determines the general slope on either side; that where it lies far from the centre of a continent we find a short and steep slope on one side, and a long and gentle slope on the other; the best examples being the chains of the Andes, 50 to 100 miles from the Pacific and 2,000 miles from the Atlantic. Even in Great Britain, where the mountains are on the west side, we have a western slope that is short and steep, compared with the long and gentle slope towards the North Sea.

45. **Maps.**—Careful study of the maps in a good physical atlas is the best way of learning the physical features of a country. Books on general geography deal with the physical features of the continents. Here we confine ourselves to a few remarks on the modes of representing physical features on maps. Rivers, the outline of lakes, and the coast-line are represented by lines that follow their actual windings. In the case of mountains and other irregularities of surface there is more difficulty. Often the slopes of mountains are indicated by shading, the summit and the highest line of a chain being left unshaded. With the aid of colours —as green for land below 1,000 feet, different shades of brown for land above 1,000 feet, and various shades of blue for various depths of the sea—differences of level are made still more striking. (*See* Chapter X.)

Particular attention should be paid to the scale on which a map is drawn, as indicated in one corner or on the margin. The scale may be expressed as a fraction: $\frac{1}{100000}$, or as a ratio: 1 : 100,000. This means that one inch on the map represents the number of miles in 100,000 inches. In large-scale maps, such as a scale of one inch to

the mile (1 : 63,600), contour lines, connecting places of equal elevations, are very useful in indicating height and slope. Thus, in fig. 49, A represents a hill, the form of which is indicated by contour lines at intervals of 100 feet. B shows a profile or side-view of the same hill along the section *a b*. It is easy to see that the contour lines get closer the steeper the slope, and wider apart the gentler the slope. By using shading as well as contour lines, and making the shading darker the steeper the slope, as in C, a still better idea of the hill is obtained. (For Methods of Map Projection, *see* Chapter XI.)

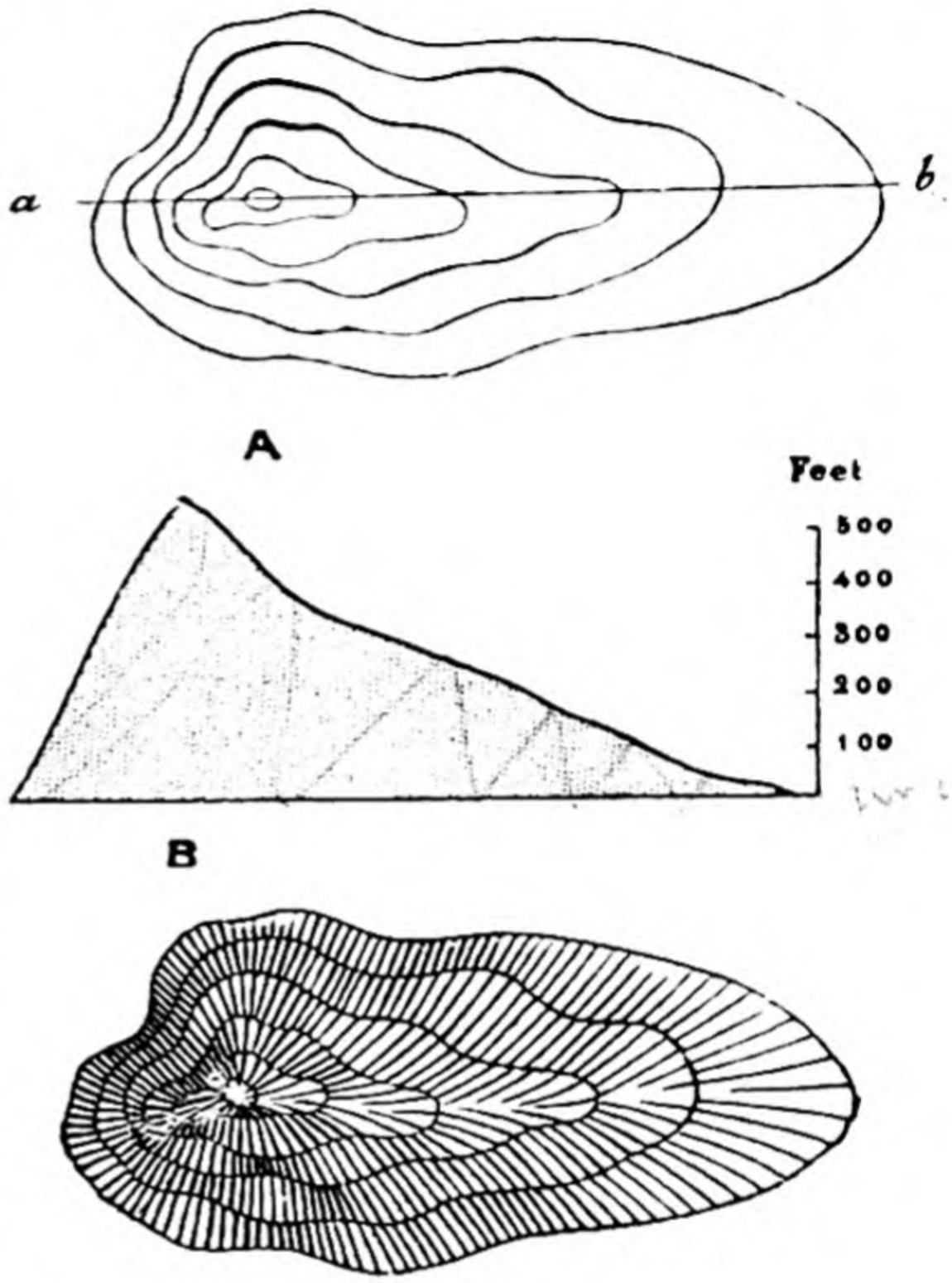


FIG. 49.

46. **Plains and Plateaux.**—Low-lying regions of level or slightly undulating country not more than 1,000 feet in height are termed **plains.** Thus, in North America, between the Rocky Mountains in the West and the Appalachian mountain system in the East, a vast plain stretches from the Gulf of Mexico in the south to the Arctic Ocean on the north. A large plain extends across Europe from the North of France, through the Netherlands and Germany, to the Ural Mountains. It is continued, indeed, in Asia across Siberia. Plains differ greatly in fertility according to their climate and soil. Where there is no rain, as in the North of Africa, we find a sandy waste, the Desert of Sahara. This is a broad barren plain south of Morocco, Algiers, and the Mediterranean, between the Atlantic and the Valley of the Nile. It rises here and there into hills, and the sun's heat is intense. Nothing grows except in small spots where springs come to the surface. Such little spots of water-supply and vegetation are known as **oases.** Many of the plains in the world have special features and are known by special names—**steppes** in South-east Russia, **tundras** in Siberia, **prairies** in North America, **llanos, selvas,** and **pampas** in South America (*see* Glossary). A **plateau,** or **tableland,** is a comparatively level tract of land at a considerable elevation above the sea—an elevated plain, in fact, that, like a lowland plain, may be trenched by river valleys, and here and there rise into high hills. In fact, the distinction between a plain and a plateau is not very well marked, the Sahara (1,500 to 2,000 feet high) being often spoken of as a barren, sandy tableland. The Spanish Peninsula is the chief tableland of Europe, rising rather suddenly from the sea-level to an average height of 2,000 feet and crossed by several **sierras,** or mountain ranges, between which several

rivers run into the Atlantic. In Africa we find the plateau of Abyssinia, 7,000 feet above the sea-level, the gathering-ground of the waters of the Atbara and Blue Nile in the rainy season. A great plateau in the equatorial regions, 3,000 to 4,000 feet, contains several lofty peaks and a number of large fresh-water lakes, one of which, the Victoria Nyanza, may be regarded as the headwaters of the White Nile, and another of which, Tanganyika, drains to the Congo. This great plateau stretches southward to the Zambesi, a river running in a steep course to the Indian Ocean and dividing the great plateau of the centre from the south plateau. The plateau south of the Zambesi sinks to the sea by a series of terraces (fig. 50). (*See* Glossary, 'Karroo.')

The lofty irregular **Pamir** plateau, N.W. of India, mostly above 12,000 feet, forms the highland centre of Asia, and is spoken of as the 'Roof of the World.' From this plateau as a centre mountain ranges radiate east and west. The Hindu-Kush runs south-west, the Himalayas south-east, the Karakorum parallel to the Himalayas, the Kuen Lun eastwards, and the Tian Shan north-eastwards. Between the Himalayas and the Kuen Lun extends the great plateau of Tibet, 13,000 feet high; and between the Kuen Lun and the Tian Shan lies the Gobi Desert, a plain of drifting sand 3,000 feet high. In India, the southern part of the peninsula contains the Plateau of the Deccan, with its lofty

FIG. 50.

western edge, the Western Ghats, and a gentle slope to the east, along which the rivers run.

In North America, the great central plain rises into a plateau as we approach the Rocky Mountains. On the west of the Rocky Mountains, and between this range and the Pacific coast range called Sierra Nevada, is a vast region of *inland drainage* larger than France, forming the plateau termed the **Great Basin.** It is from 4,000 to 5,000 feet high in its broadest part, and contains many salt lakes, such as the Great Salt Lake, Lake Utah, Carson Sink, etc. Those in the north-east are relics of a large extinct lake termed Lake Bonneville. Soda Lake and Death Valley are great depressions in the Great Basin. In South America, between parallel chains of the Andes, lies the lofty plateau of Bolivia, 12,000 to 13,000 feet high. It contains the fresh-water lake Titicaca, the highest navigated lake of the world. Between the two Americas we find the Mexican Tableland, 5,000 to 6,000 feet high, on which the climate is temperate and healthy compared with the hot and deadly tracts at the foot of the plateau by the sea.

47. **Structure of the Land.**—The upper or outer layers of the earth, called its **crust,** and forming but a small fraction of the whole, have been found to consist of different kinds of rock. A **rock** is thus any mass of natural substance forming part of the earth's crust. In this sense, sand, gravel, and soft clay are as much rocks as hard limestone and granite. Rocks

are composed of various inorganic substances, termed minerals, and these have a definite chemical composition and definite physical properties. The most abundant mineral in the earth's crust is a chemical compound termed **silica.** Silica not only occurs as a separate rock in quartz and flint, but it assists in forming other minerals, as felspar and clay. Next to silica and its combinations, the most abundant rock-forming minerals are the carbonates of lime and magnesium. **Ores** are minerals from which useful metals may be extracted.

Many of the rocks forming the earth's crust are arranged in layers or strata. These **stratified** rocks are distinguished from others not only by their arrangement in layers, but by possessing evident marks that indicate that they have been in most cases derived by wear and tear from fragments of older rocks, and deposited as sediment by the agency of water. Hence stratified rocks are also called **aqueous** or

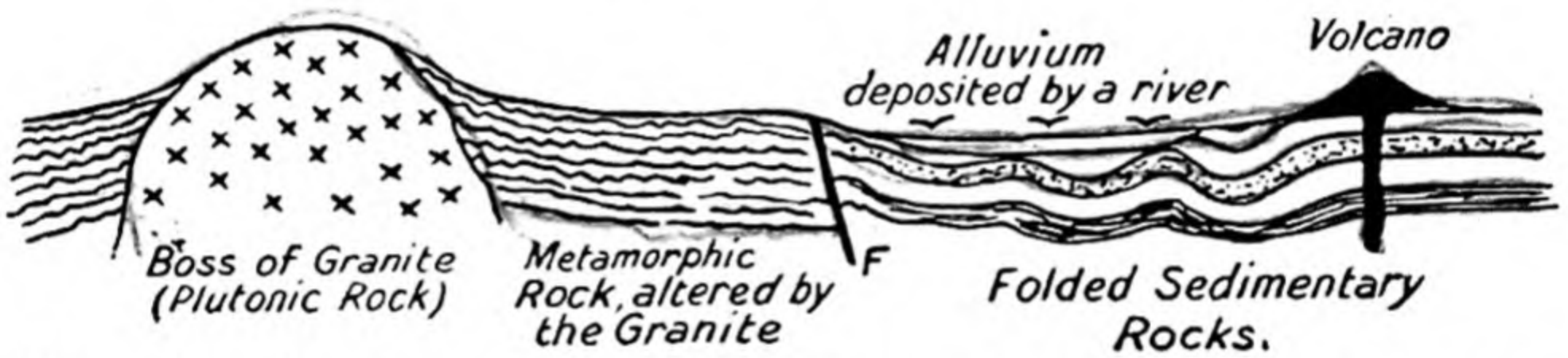


FIG. 51.—SECTION THROUGH THE EARTH'S CRUST SHOWING THE DIFFERENT CLASSES OF ROCKS.

sedimentary rocks. Stratified rocks also contain remains, or impressions of remains, of animals and plants, termed **fossils.** Sandstone, limestone, and shale are examples of stratified rocks. **Unstratified** rocks possess no marks of bedding, but are of eruptive or **igneous** origin, having been driven out from the interior of the earth. They usually possess a crystalline structure. Examples are lava, basalt, and granite.

Unstratified rocks are usually found in mountainous districts, having been pushed through the overlying strata, and rising up as conical hills, or filling up fissures in sheets as walls or **dykes.**

A certain class of rocks, originally sedimentary or sometimes igneous, have been so altered by heat and pressure as to lose their fragmental character and get a more or less crystalline structure. These are called **metamorphic rocks** (Gk. *meta*, change; *morphe*, form). Examples are slate, schist, and gneiss.

Organic rocks are such as are formed from the remains of

animals and plants. Coral, chalk, and coal are examples. Coal consists of the remains of vegetable matter that has been buried for ages in the earth. By decomposition and compression it becomes richer in carbon and more compact, and can thus be dug up from its bed and used as fuel. **Chalk** is mainly composed of the minute shells of tiny gelatinous animals termed Foraminifera, as may be seen on examining a little of the powder under a microscope (fig. 40). These small creatures live in countless numbers in the ocean, and have the power of secreting the carbonate of lime from sea-water, and when they die their shells accumulate at the bottom. By some upheaval this deposit may get raised and form part of the dry land, and, being compacted together, chalk is the result. Coral reefs and islands are formed of rock also consisting of carbonate of lime. Myriads of tiny

FIG. 52.—ROCKY ISLAND BORDERED BY CORAL REEFS. (After Dana.)
f, fringing reef ; *b*, barrier reef ; *h*, *h*, openings in the reef.

soft-bodied animals (not insects), termed coral polyps, live in colonies attached to rock near the surface of warm seas, and secrete carbonate of calcium from the sea-water. This remains after the animals die, and the hard parts thus accumulating form rings of rock (**atolls**), or ridges, called **barrier reefs** and **fringing reefs** (*see* Glossary). Such reefs and islands abound in the Central Pacific, the East Indies, the Indian Ocean, the Red Sea, and near the West Indies, and thus these tiny creatures assist in building up new land. (*See* fig. 77.) (*See also* Glossary, 'Calcareous.')

48. **Volcanoes.**—Observations on the temperature of the earth's crust in mines, borings, and tunnels show that beyond a depth of 40 or 50 feet the crust is not affected by the temperature of the surface, but that below this depth there is a regular increase of temperature of about 1° F. for every 50 feet of descent. Hence at a depth of two or three miles there must be such a high temperature that the rocks will be melted if they can find room for expansion. Volcanoes are conical hills formed of erupted matter, and having at the top a cup-shaped cavity,

termed the **crater,** from which a tube or pipe passes downward into the heated interior. At times they discharge quantities of melted rock called lava, hot stones, dust, steam, and other gases. An eruption usually begins with a mighty shake of the mountain, followed by huge ball-like masses of steam, gases, and volcanic dust, that rise in a column if the wind is still. Ashes and stones quickly follow, and then the lava rises up, and either overflows the lip of the crater or bursts through fissures in its sides. The steam-cloud beginning to condense, a great downfall of rain occurs, sweeping the loose volcanic dust down the mountain sides, and forming torrents of mud lava, that often do more destruction than the real lava stream. The larger masses, volcanic blocks, scoriæ, etc., fall on the mountain sides, and help to increase its mass, while the ashes are often carried by the wind to enormous distances. The lava stream sometimes flows several miles before it becomes solid, and it often takes months to cool.

In 1902 violent and destructive eruptions occurred in the West Indies, the eruptions proceeding from the volcanic cone Pelée in Martinique and from the cone Soufrière in St. Vincent. A special feature of these eruptions was the dense clouds of scorching volcanic dust and sulphurous acid vapours that rolled down the mountain and destroyed all living creatures that they reached. The town of St. Pierre, 2½ miles on the south side of Pelée, was buried beneath volcanic ashes and every living creature killed by the suffocating dust and gases.

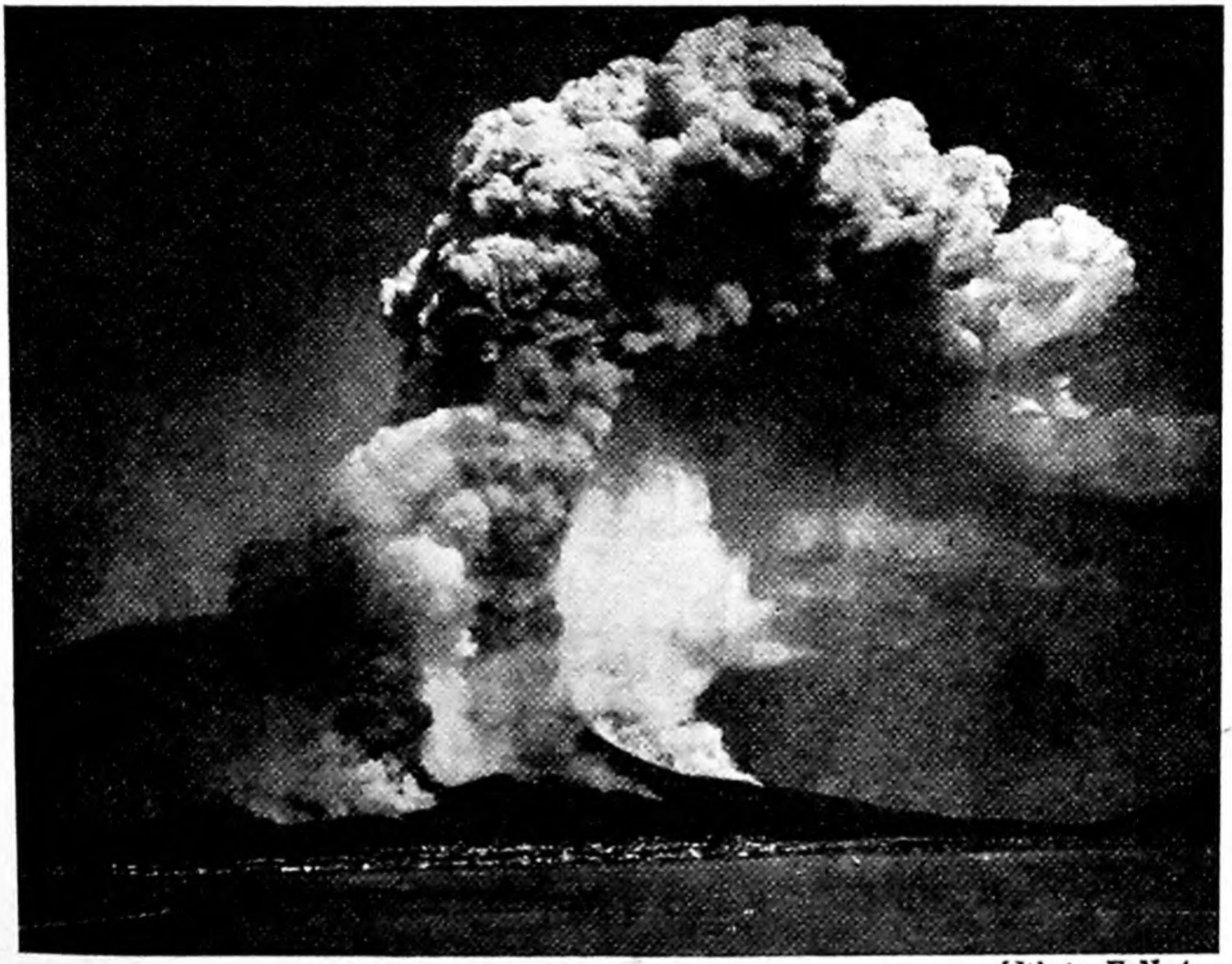
It is estimated that there are about 200 active volcanoes on the globe. Many formerly active have now become **extinct,** as those in the Auvergne district of France. Others discharge only a cloud of steam, and are said to be **dormant,** though renewed activity may occur at any time.

Volcanoes approaching extinction may emit steam and gases through crevices in the ground. This is known as the solfataric stage.

Many volcanoes are distributed on the border of the sea, especially where high mountains are near great ocean deeps. (*See* Map 13, p. 218.)

Another interesting fact regarding their position is that they are found in all regions of the globe, from Iceland and the Aleutian Islands, through the tropics to the Antarctic continent, though they are more numerous along certain lines, as will be seen on reference to a map, which are lines of weakness in the earth's crust. Over 100 of the active volcanoes, too, are found on the coast-lands or islands of the Indian and Pacific Oceans. On the east side of the Pacific we can trace a line of volcanoes through the lofty chain of the Andes, then through Central America and along the west coast of North America. (The volcano of Jorullo, on the coast of the Mexican tableland, is noteworthy from the fact that it was entirely built up to a height of over 1,300 feet in a single eruption in 1759.) This line then crosses over from North America, by the Aleutian Islands, to Kamtschatka on the western side. In Kamtschatka there are 12 active volcanoes, in the Kurile Islands 10, and in the Japanese islands over 20. From Japan the line of volcanoes

passes through Formosa and the Philippine Islands to the Malay Archipelago. In this great group of islands volcanic activity seems at its height. In Java there are about 40 volcanoes, and in Luzon and the Philippines 21. In the Malay Archipelago the volcanic line bifurcates. One branch goes westward through Java and Sumatra, along the eastern side of the Bay of Bengal; another branch turns to the south-east through Celebes, New Guinea, the Solomon Islands, and the New Hebrides. A continuation of this line passes into New Zealand, and to Mount Erebus and Mount Terror in the Antarctic continent.



[*Photo E.N.A.*

FIG. 53.—A VOLCANO IN ERUPTION, SHOWING PINE-TREE COLUMN OF STEAM, FALLING RAIN, ASHES, AND STEAM FROM LAVA STREAMS FLOWING DOWN THE MOUNTAIN SIDES.

Another great volcanic line may be traced down the eastern side of the Atlantic, from Jan Mayen and Iceland, through the extinct volcanoes of the Faroe Islands and those of the West of Scotland, to the Azores, Canaries, Cape Verde, and other volcanic islands lying off the coast of Africa. This line appears to be connected with a great submarine ridge that runs down the middle of the Atlantic. One branch from this passes into the West Indies, where there are six active volcanoes, while another branch passes into the Mediterranean. Vesuvius is the only active volcano on the mainland of Europe, but on the islands of the Mediterranean there are about five—viz., Stromboli and Vulcano in the Lipari Islands, Etna in Sicily, Santorin and Nisyros in the

Grecian Archipelago. It is believed that this linear arrangement of volcanoes is owing to the fact that they occur on lines of fissures in the earth's crust.

49. **Earthquakes.**—An earthquake is the name applied to a trembling or shaking of the ground. They are often preceded by internal noises, and then followed by a shock that causes either a rapid up-and-down movement of the ground or a wave-like motion of the surface. So great may be the force that in some cases buildings are hurled to the ground and gaping fissures produced in the earth's crust. The bed of the sea may share in the disturbance and huge destructive waves be forced inland. Earthquake regions are closely associated with volcanic districts, the two phenomena being probably produced by such forces as expanding steam suddenly produced in the earth's crust, and the crumpling of the crust by contraction. Memorable earthquakes are that of Lisbon in 1755, that at Manilla in 1863, one in Peru in 1868, in Chili 1880. But the most terrible earthquake of recent times was that of September 1923, which destroyed Yokohama and part of Tokyo, Japan, when 100,000 people perished. An earthquake accompanied the tremendous volcanic eruption at Krakatoa, between Java and Sumatra, in 1883, and huge waves swept the coasts of these islands, while the volcanic dust was sent to great heights and carried more than 1,000 miles.

50. **Slow Movements of Elevation and Subsidence.**—Besides the sudden and violent movements of the earth's crust accompanying volcanic eruptions and earthquakes, the internal forces within lead to very slow elevation of land in some places and sinking in others. Thus the shores about the middle of Sweden are slowly rising, as is proved by former high-water marks, now never reached, and by marine shells at a distance of 100 feet above sea-level. Certain parts of South America have such shells at heights of 1,000 feet above high tide. **Raised beaches** (*see* Glossary) in certain parts of Britain, Norway, etc., prove slow elevation. **Submerged forests** on the coast of Norfolk and elsewhere prove slow subsidence, as do also the quays and buildings now found beneath the sea in South Sweden and on the west coast of Greenland.

CHAPTER VI

DENUDATION, OR THE SCULPTURE OF THE LAND

51. Besides the three subterranean agents that produce alterations in the surface of the land—volcanoes, earthquakes, and slow movements of the crust—there are agents by which the surface of the ground is broken up and the material carried away, so that the face of the globe is being constantly carved into fresh outline. The general process by which the

surfaces of rocks are split up or broken asunder, and the loosened material removed so as to expose parts previously covered, is called **denudation** (L. *denudo*, I lay bare). **Erosion** (L. *rodo*, I gnaw) and **disintegration** are other words applied to the wear and crumbling of rocks, and the loose material arising from this waste is often termed **débris,** or **detritus.** The chief denuding agents are :—(1) The atmosphere, (2) rain, (3) running water, either above or below ground, (4) ice.

Each acts both as a producer and carrier of *débris*, or waste material, and in some cases the agents act in combination.

[*Photo Raddy*

FIG. 54.—The 'CHEESWRING' NEAR LISKEARD, CORNWALL (granite).

52. **Action of the Atmosphere on Rocks.**—The oxygen of the atmosphere is an active agent that enters into new combinations with certain bases in the rocks and leads to a breaking up of their surfaces. Thus rocks containing the lower oxide of iron take up more oxygen to form the red or brown oxide. The carbon dioxide of the air also assists in forming new compounds, especially when it is dissolved in water (*see* Par. 53). The varying heat of the atmosphere at different times also leads to contractions and expansions of their surfaces that result in loosening particles. The action of the wind may be put under this head. It often drives fine, sharp particles of sand against outstanding masses of rock, grinding away their surfaces, especially at the base. The rock mass thus becomes undercut, or worn away below, so as to get the appearance of an anvil, or one-legged table. Wind also acts as a transporting agent, driving the sand from the shore inland, and often forming the sandhills termed

dunes. The **Landes** south of the Garonne are areas covered with sand drift.

53. **Action of Rain.**—The action of rain on rocks is partly **mechanical** and partly **chemical.** Its fall serves in loosening the softer rock and soil, and, as it flows over the surface, particles are carried away, in some cases leaving an **earth-pillar** capped and protected by a flat mass of rock. A portion, getting into crevices, becomes frozen in winter time, and as expansion takes place during the act of freezing, portions are thus split off. **Frost** is thus a powerful agent of destruction. The action of frost, heat, rain, and the gases of the atmosphere in altering the texture and breaking up the surface of rocks is often termed the **weathering** of the rocks. In passing through the air rain takes up slight quantities of carbonic acid, and water charged with this acid can slowly form soluble combinations with the lime, magnesia, and potash of the felspar in granite, thus helping in the formation of kaolin, or china clay. But the chemical action of solution is best shown on chalk, limestone, and other rocks formed of calcium carbonate, for the slightly acid water, sinking into the ground, and getting more carbon dioxide from decaying animal and vegetable matter, will in time dissolve out so much rock as to form great **caves** and underground passages in limestone districts. Water containing limestone in solution and dropping from the roof of a cavern evaporates, and the carbonate of lime is thus deposited again. In this way are formed the icicle-like masses termed **stalactites** found hanging from the roof of limestone caverns. The drops that fall on the floor also deposit their carbonate of lime, and form pillars termed **stalagmites** (fig. 136). Of limestone caverns with stalactites and stalagmites formed in great part by the dissolving action of the underground water, the most famous are that of Adelberg in Austria, the Grottoes of Han in Belgium, the Mammoth Cave in Kentucky, and the Jenolan Caves in New South Wales.[1]

54. **Action of Running Water.**—Under this head **springs** and **rivers** are included. The rain that falls on the ground is partly evaporated at once, part flows off into streams, and part sinks into the ground, to reappear after a longer or shorter subterranean course. The amount of water that flows off

[1] Humus acids derived from soil and decaying vegetable matter also aid the solvent action of the water passing along and through the ground.

the surface or sinks into the ground is determined by the nature of the soil and surface rock. Some rocks, like sand, gravel, and chalk, are very porous or permeable, and absorb much water; others, like clay, are impervious. Springs consist of water flowing out at the surface from the rocks. Where a thick layer of permeable rock rests on an impermeable layer, water passes through the permeable one, and accumulates until the pressure of the liquid causes the outflow of a spring on a hillside at the junction of the two layers. In dry weather, especially if the impermeable bed contains hollows, the spring may cease to flow for a time. By digging a pit through the upper rock below the point of saturation a well (w) will be formed, from which water may be pumped or lifted by a bucket.

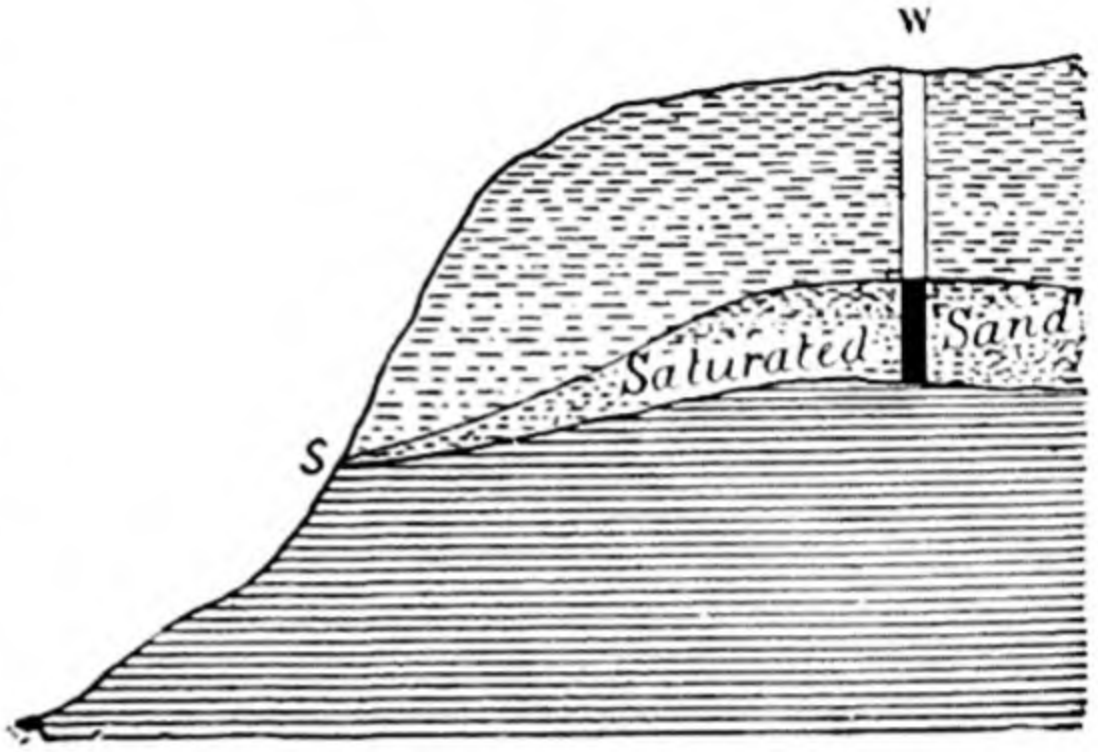


FIG. 55.—A SPRING.

Where a permeable bed of rock lies between two folded impermeable beds a well may be sunk in the middle of this basin, and the water will rise up above the surface. Fig. 56 illustrates the arrangement of strata to produce such an

FIG. 56.

a, Artesian well; *b*, *b*, Impermeable strata; *c*, *c*, Porous stratum; *d*, *d*, Collecting surfaces.

artesian well. When the porous bed C C is saturated up to D the water in the boring at A will rise to the same level. Springs of hot water rising from great depths, and known as **thermal springs**, are found in many parts. Such water generally contains far more mineral matter in solution than ordinary spring water, and therefore most thermal springs are **mineral springs** also. The water of the Bath springs has a temperature of 115° F., and that at Karlovy Vary (Karlsbad) a temperature of 150° F.

Certain hot springs in volcanic districts are known as **geysers** (*see* Glossary).

54*a*. **Action of Rivers.**—Let us now see how **rivers** act as agents that change the surface of the land. The land area from which a river and its tributaries and affluents collect their water is called its **catchment** basin; the land which separates adjoining river basins is called a **water-parting,** or **watershed,** though the term watershed is more correctly applied to the slopes down which the rivers run. The **source** of a river is its origin, and may be found in springs or rills, in glaciers or in lakes. Rivers act on the land in two ways:—

(1) They act as carriers of sediment and of matters in solution, and the sediment forms deposits that give rise to deltas, sandbanks, and bars.

(2) They denude the surface by their erosive action, and thus give rise to ravines, cañons, and valleys.

The rain that streams off the ground into small rills and brooks brings into these small streams particles of matter swept off the surface, as well as matter held in solution, and more *débris* is derived from the river bed and banks. In the upper part of their course, where the fall is great, the carrying power of a river is scmetimes enormous. Huge blocks of rock are hurled onwards, and their sharp angles rubbed off, so that water-worn boulders and pebbles are always rounded (fig. 1).

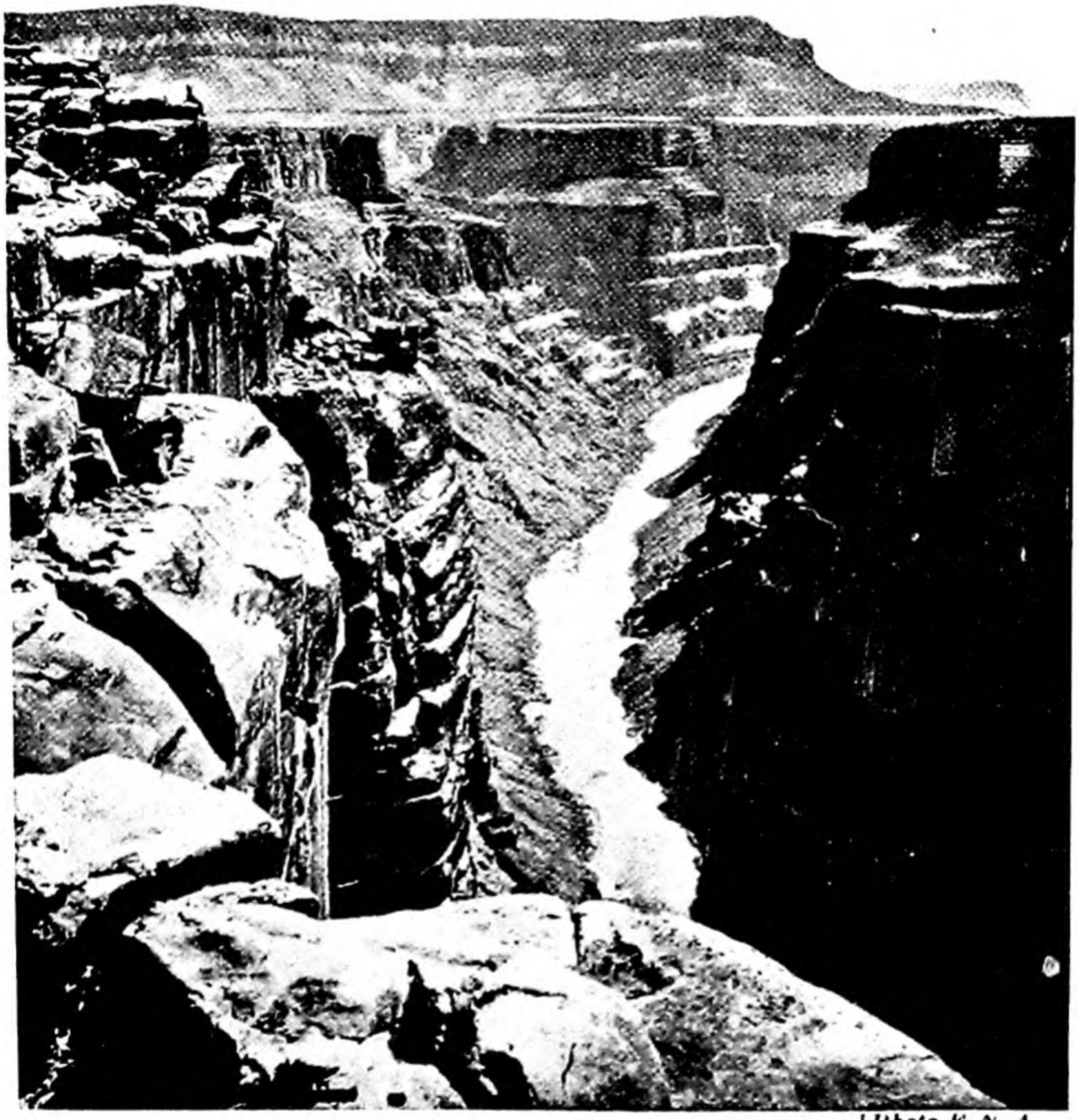
FIG. 57.—SECTION ACROSS A RIVER VALLEY, WITH GENTLE SLOPES WHERE THE BANKS ARE FORMED OF SOFT ROCK, NARROW AND STEEP-SIDED WHERE THE STREAM HAS CUT DOWN TO HARD ROCK.

As the torrent diminishes in speed the stones and material carried onwards become less, until near its mouth mud and sand alone are swept forward. Flood-time is the time when most matter is carried and most destructive work effected. The eddies produced in a rushing stream on a rocky bed often cause the stones and sand to revolve, and in this way are formed smooth rounded cavities termed **pot-holes.**

To illustrate this denuding action of rivers, it is said that the Mississippi carries down every year enough sediment to cover a square mile to a depth of 268 feet, while the Ganges and Po carry even more.

As eroding agents they wear away their beds and banks, thus giving rise to valleys, either wide and open as that of the Thames, or deep and narrow like the gorges of the Upper Rhine or the cañons (*see* Glossary) of the Colorado and its tributaries. Both kinds of valleys are often found in the course of the same river. Where the banks are formed of soft rocks, and exposed to frequent rains, the valley is wide and open, for the atmospheric agencies are constantly wearing away the sides, while the river is deepening its channel. Where the banks are formed of hard rock, or even where the rock is soft but very little rain falls, as in deserts, a steep-sided gorge is worn out by the abrading action of the *débris* swept along by the stream, and this gorge is con-

tinually becoming deeper. As an example of river action alone, without much weathering of the banks, the cañons of the Colorado River, running into the Californian Gulf, may be given. Here the river and its tributaries traverse a rather arid plateau, hemmed in by mountains, from which the streams derive their supplies. The main stream



[*Photo E.N.A.*

FIG. 58.—GRAND CAÑON OF COLORADO RIVER, WITH SIDE CAÑONS, IN THE PLATEAU IN ARIZONA.

travels along the Grand Cañon, an enormous chasm about a mile wide, with walls exceeding 4,000 feet in height. As the beds on opposite sides of this cañon exactly correspond, and as river gravel is found on its sides at various heights, it is evident that the chasm is the work of the river alone, and not of any earthquake or other violent convulsion.

The gorge of the Niagara between the Falls and the plain at Queenstown, seven miles distant, is also an example of the work of a river. (*See* Glossary, 'Waterfalls.')

What becomes of the land-waste, or *débris*, brought about by a river? In the upper part of its course, where the slope is steep (50 or 70 feet a mile) it is often a roaring torrent, hurling along huge boulders, pebbles, gravel, and sand to lower levels, and continually deepening its bed. Reaching its middle, or valley course, the current becomes slower, and only the smaller pebbles, with sand and mud, are moved on. Slight obstacles, as harder rock on one side, turn its course, and give it the serpentine windings so often found. On the concave side the banks are gradually worn away, while deposits of shingle are found on the convex side. Where two sharp bends are close together a shortened straight passage ⌒ will often be made. In times of flood the river may overflow its banks, depositing in the valley gravel, sand, and mud, termed **alluvium.** Alluvial soils are thus formed in the wide river valley, the outer edge of this alluvial deposit being the level of highest flood. As the river deepens its channel the flood no longer reaches its first height when in flood, and a new deposit of alluvium takes place in the valley at a lower level. In this way a valley may come to show deposits of mud, sand, and gravel at different levels, termed **river terraces.** (*See* Glossary, 'Flood-plain.')

In the lower part of its course the current gets still slower, and at ordinary times only the fine sand and mud are held in suspension. It deposits now more than it erodes, and in flood-times it overflows the adjoining plains, and deposits most of its sediment close to the banks in broad ridges. When the amount of mud is very great, as in the Mississippi or the Yellow River of China, the river bed also gets silted up, and the stream may thus come to flow inside a channel having an embankment or naturally formed wall of sediment higher than the surrounding plain. These natural walls of sediment on the Lower Mississippi are called **levées,** and are carefully strengthened, in order to protect the dwellers on the plain from the disastrous effects of the inundation that follows a breach.

The salts *dissolved* in river water and removed from the land amount to a very great quantity in the course of time, and these are added to those already in solution in the water of the sea. In every 5,000 years it is estimated that rivers carry their own weight of dissolved rock to the sea.

55. **Deltas.**—Where a river enters the sea its current is so checked that a large part of the sand and mud still in suspension is deposited, and if the seas have but small tides and feeble currents, the sediment accumulates so far that at last a tract of flat alluvial soil forms above the level of the sea, and divides the stream up into several interlacing branches, some of which have separate outlets or mouths. Such a tract of alluvial deposit at the mouth of a river is called a **delta,** because that of the Nile, with its head at Cairo, where the river splits into two main branches, resembles in form the Greek letter *delta* (Δ) (fig. 59).

Other notable deltas are those of the Mississippi, the Ganges and Brahmaputra, the Rhine (forming most of Holland), the

Rhone south of Avignon, and the Po. The Mississippi delta, beginning at New Orleans, covers a great area, forming a

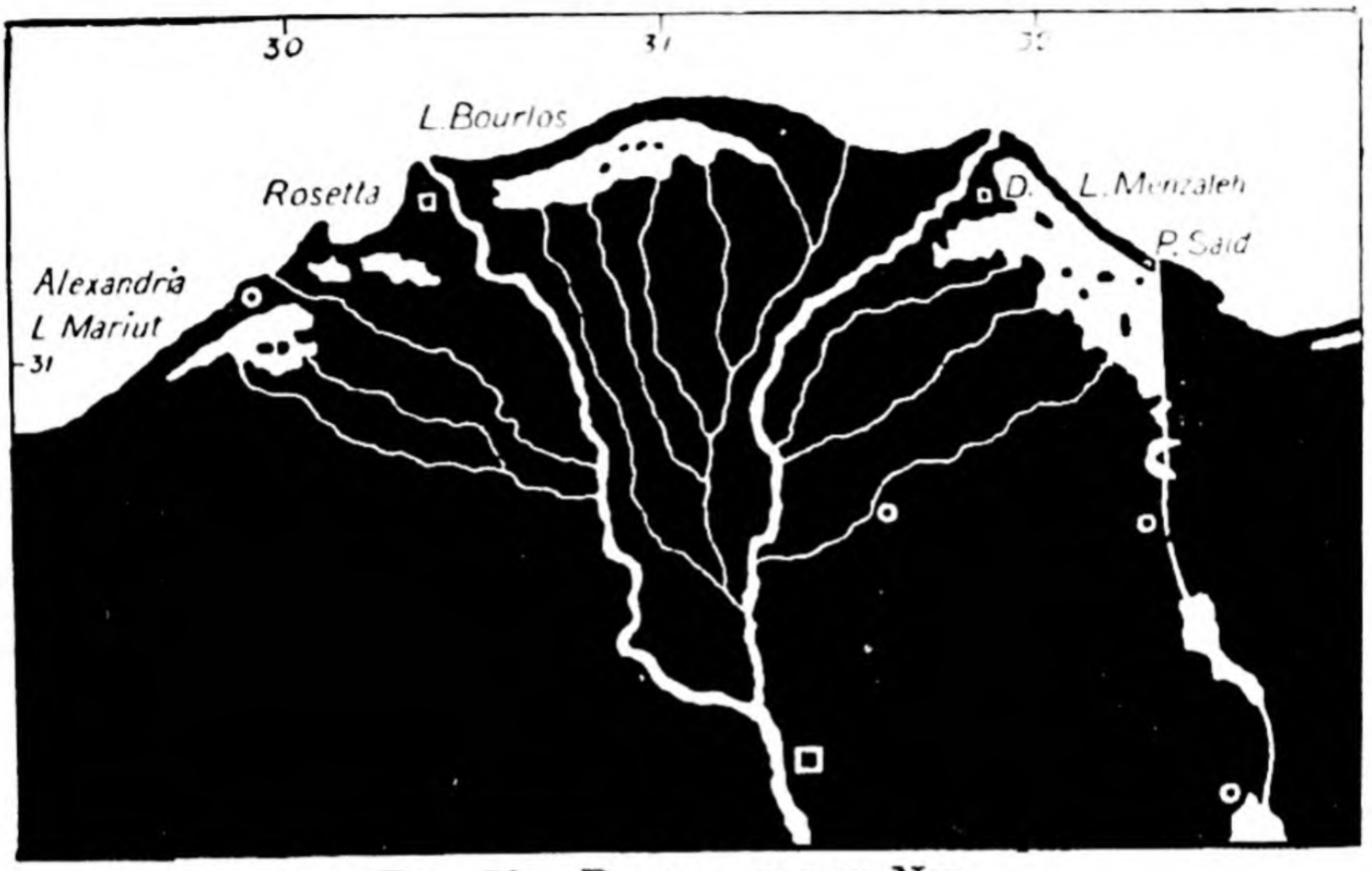


FIG. 59.—DELTA OF THE NILE.

narrow peninsula stretching out into the Gulf of Mexico. Its goose-foot head is traversed by branches of the river, and advances about 300 feet every year (fig. 60). The Rhone has really two deltas, one where it enters the sea, and one where it enters Lake Geneva. On entering the lake it is a swift, turbid stream, but on leaving its waters are quite clear. An old Roman town, now called Port Vallais, was once situated on the edge of the lacustrine delta (L. *lacus*, a lake), but it is now more than half a mile inland.

Many rivers do not form deltas in the sea because the sediment brought down is either carried out to sea by the strong tides and currents, or spread out in the estuary as **sandbanks** and **shoals.** If the estuary be narrow, a ridge

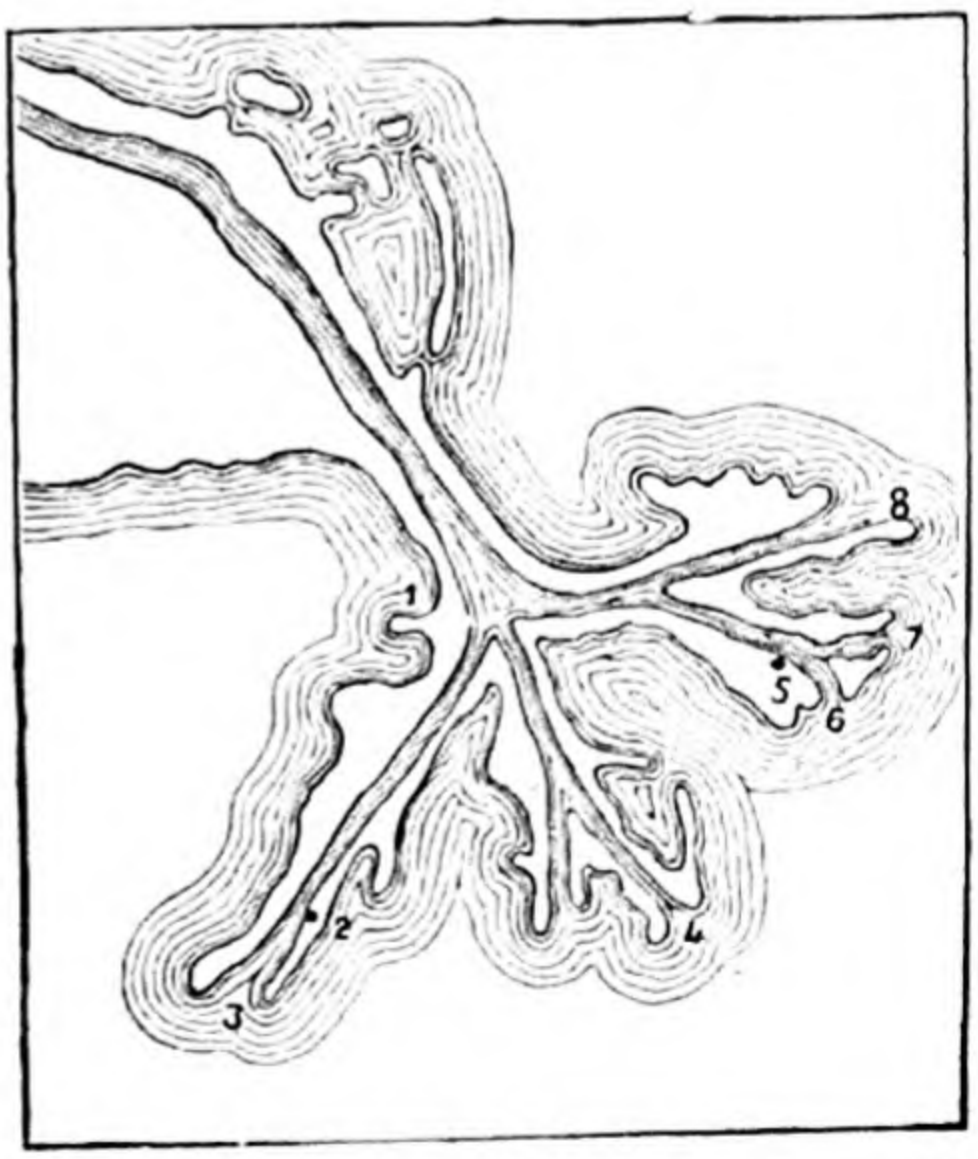


FIG. 60.—LOWER PORTION OF DELTA OF MISSISSIPPI.

3, 4, 6, 7, and 8, channels.

of sand and shingle may arise across the mouth from the sediment of the river and the material washed in by the tide, thus forming a **bar** that impedes navigation. Yet, though there are fairly strong tides in the Bay of Bengal, so enormous is the detritus brought down by the Ganges and Brahmaputra that the combined delta not only formed, but it goes on increasing.

[*Carthew and Kinnaird.*

FIG. 61.—GLACIER LANDSCAPE, SHOWING THE ORIGIN IN DISTANT SNOW-FIELDS.

On the surface are seen great fissures (crevasses), and lines of stones and rubbish (moraines).

56. **Action of Ice.—Glaciers.**—In the form of glaciers and icebergs ice acts both as a denuding tool and a transporter of the waste of the rocks. In the cup-shaped upper end of those mountain valleys above the snow-line the snow accumulates year after year. By pressure, and by the freezing at night of the water that melts at the surface and trickles into the crevices, this parent mass of snow becomes compacted into a heap of **granular** ice termed **nevé,** or **firn.** The ice-granules of a glacier consist of ice-crystals fitting closely into one

another. From the nevé the lower portions are squeezed out, and, driven by gravity and the pressure behind, the ice travels down the mountain valley for several miles as a **glacier,** or river of ice, often several hundred feet deep. It moves slowly onward, somewhat like a viscous mass, breaking at times, and then getting frozen together again (*see* Glossary—**Regelation**), and splitting from its brittle nature where its bed is steep, or on turning a corner, into deep fissures, termed crevasses. Its onward motion has been proved by driving a straight row of stakes into the ice opposite two fixed points in the rock on opposite sides. After a year the stakes are found to have moved on, those nearest the middle moving farthest. Thus, like a river, its surface and centre move faster than its sides and bottom. The frost, acting on the rocks forming the sides of the glacier, breaks off masses of rock and earth, that fall on the sides and form **lateral moraines** (L. *latus*, *lateris*, side). Two glaciers meeting, their inner, lateral moraines unite to form a middle or **median moraine,** and where a glacier is formed by the union of several others several median moraines occur. Great quantities of loose earth and stones are thus carried down to the end of the glacier, where they are deposited as a **terminal moraine.** Beneath the glacier there is a mass of rocky material often frozen into the glacier, termed the **ground moraine.** (*See* figs. 118, 130.)

The ice melting at the upper surface of the glacier during the heat of s summer's day, water pours down the crevasses or down vertical shafts, termed **moulins,** hollowing out deep pot-holes or **giants' kettles.** This water passes on beneath the ice, and, joining the water from the bottom, flows from a cave-like hollow at the snout as a stream of muddy water. The water of a glacier is turbid, owing to the rocky sediment it contains, for some of the stones of the moraines fall or are washed into the crevasses, and, becoming frozen in the sides, act as a rasp, planing and scoring the rocky channel, or themselves becoming striated and ground into powder.

The rate of flow varies very much according to the slope and the season, being as much as 60 feet a day in summer in some glaciers, but less than that in a year in other cases. Glaciers descend a considerable distance below the snow-line, the great pressure and mass causing them to melt slowly. Those of the Himalayas and Andes reach 9,000 feet above sea-level, those in the Alps 3,500 feet, those in Norway 1,200 feet, and those in New Zealand 650 feet. In Greenland, Antarctica, and Alaska the glaciers descend to the sea-level, where huge masses of ice are broken off, and float away with their load of rocks as **icebergs** (*see* Par. 36).

Changes in the mean annual temperature and the mean snowfall on the mountain cause a glacier to advance lower down or retreat higher up its valley. In the latter case it exposes its rocky bed, and often

shows polished and striated hummocks of rock, termed **roches moutonnées,** or sheep rocks, from their resemblance at a distance to the forms of resting sheep. Such *roches moutonnées* and striated blocks are found in Cumberland, Wales, and other countries now free from glaciers. They thus show that in these parts the climate was once much colder, and that glaciers once covered their surface. **Erratic blocks** (*see* Glossary) prove the same. Evidence of the great extent of ice-sheets and glaciers over districts now free from ice is also found in the occurrence in Great Britain and other countries of great masses of glacial *débris*, the remains of old moraines of all kinds. Stiff clays, called **Boulder Clays,** are the most extensive of the deposits of former ice-sheets and glaciers. Boulder clay consists of clay loaded with boulders of all shapes and sizes torn from the rocks over which ice has formerly moved. Many of these boulders show scratches or **striæ** (fig. 137) due to the sharp stones in the moving ice. Boulder clay is sometimes found in elongated swelling ridges called **whalebacks** or **drumlins.** Long ridges of gravel and sand built up by deposit in former sub-glacial streams, or perhaps marking a stage in the retreat of a glacier, are known as **eskers.**

57. **General Results of Denudation.**—The various denuding agents—the sea, the atmosphere, the frost, springs and rivers, ice—all effect waste of the rocks and land surface, and carry

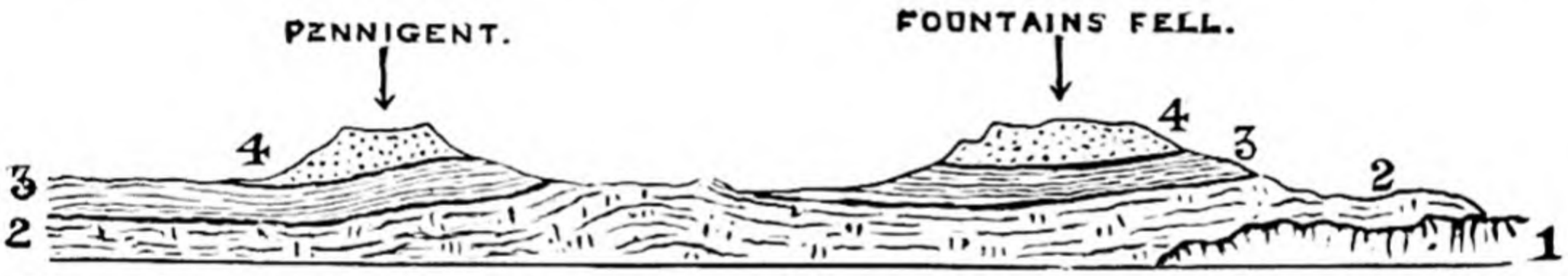


FIG. 62.—STRATA NEARLY HORIZONTAL CARVED INTO HILL AND VALLEYS.
1, Silurian strata ; 2, mountain limestone ; 3, Yoredale rocks ; 4, mill-stone grit. West Riding of Yorkshire.

away the detritus, or *débris*, from higher to lower levels, mainly to the sea. In this way lakes get filled up and disappear, and the sea bottom becomes covered with layers of sediment, some of which may afterwards be raised and consolidated into rock, for the present distribution of land and water has not always existed, and will undergo changes. The various denuding agents act unequally. In one place the land is eroded, or eaten away, at a comparatively great rate ; in another place some of the denuding agents are absent, or their power is checked by the hardness of the rock, and but little waste results. The softer, sedimentary rocks waste more quickly than the harder, igneous rocks. Various inequalities of outline are thus produced on the surface of the earth : tablelands are carved out into valleys and hills, ravines are deepened and widened, and mountains are rendered

more rugged and precipitous. Some idea of the tremendous amount of waste and the vast periods of time may be formed when it is pointed out that nearly the whole of the present scenery of Scotland, its mountains and glens, its uplands and lowlands, are mainly the result of the denuding tools that have sculptured its present surface. The level of the basin of the Ganges is being lowered at the rate of 1 foot in 2,400 years, while in the case of the Po the rate is 1 foot in 730 years. Professor Geikie calculated that the rate of denudation in the British Isles is 1 inch in 800 years, and that it would require 5,500,000 years before the land was reduced to the level of the sea. But while this crumbling of the rocks and dispersion and deposition of the material removed have been going on, other changes have been occurring which tend to counteract the levelling produced by denudation. For though the land is slowly sinking in some areas, upheaval is taking place over large tracts ; and volcanic activity, at one time much greater than now, frequently throws up immense quantities of matter in floods of lava or showers of ashes. There is thus a constant struggle between the two opposing forces, denudation and upheaval, sea and land slowly but constantly changing places to a certain extent.

Poetry has recognised how the earth's surface changes, for Tennyson wrote :

There rolls the deep where grew the tree.
Oh, Earth, what changes hast thou seen !
There, where the long street roars, hath been
The stillness of the central sea.

The hills are shadows, and they flow
From form to form, and nothing stands ;
They melt like mist, the solid lands,
Like clouds, they shape themselves and go.

CHAPTER VII

CLIMATE

58. The **weather** of any place is the condition of the atmosphere as to temperature, barometric pressure, wind, moisture, cloud, etc., at a certain time. **Climate** is the average condition of the weather for a considerable period. It is thus possible to have occasional bad weather in a place of very good climate. The Meteorological Office now publishes a daily weather

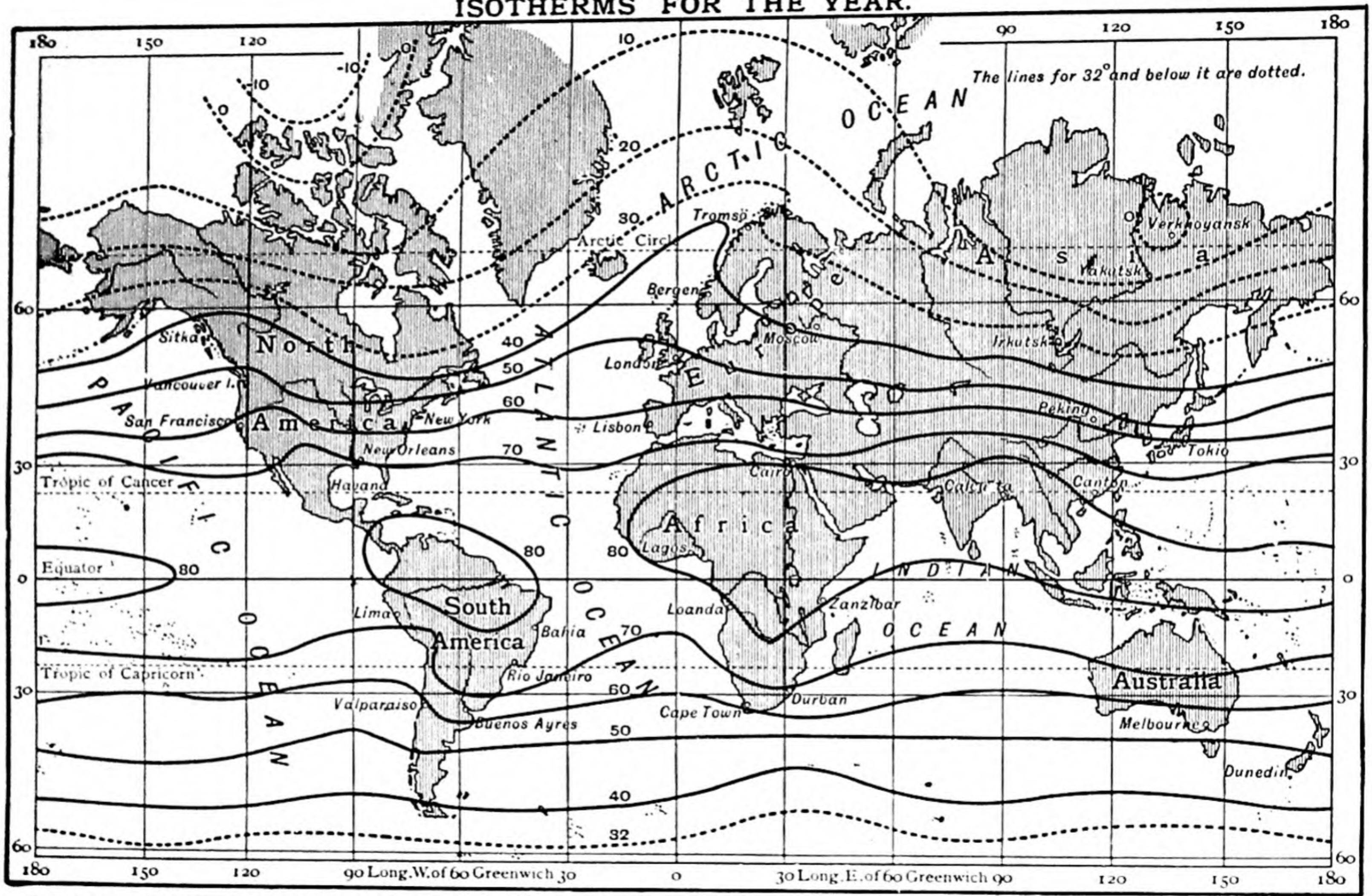
chart covering a large part of the Northern Hemisphere, and weather reports, with forecasts, are broadcast several times daily and published by the papers. On the charts are marked isobars, temperature, direction of wind, and state of the sky as to cloud, and these vary frequently. But the *average* state of the atmosphere with regard to temperature, rain, and other conditions depends on fairly well-defined causes, so that the climate of any district can be set forth with fair accuracy. The chief causes that determine the climate of a place are: (1) Latitude, or distance from the equator; (2) altitude, or height above the sea-level; (3) distance from the sea; (4) prevailing winds; (5) ocean currents.

59. **Effects of Latitude on Climate.**—Although the sun shines for an equal length of time during a year in all latitudes, yet the heating effects of his rays on the earth vary greatly in different parts. The nearer a place is to the equator the more vertical do the sun's rays fall upon it, and, consequently, the greater is the amount of heat it receives (Par. 7). Hence, as we pass from the equator the sun's rays fall more and more obliquely, and the same amount of heat-rays are spread over an increasing area, and have to pass through a greater thickness of atmosphere. The total quantity of heat received per square yard thus diminishes as the latitude increases, and hence **the mean temperature of the air, which is the main element of climate, diminishes with increase of latitude.** At and near the equator the mean yearly temperature is just over 80° F., in latitude 30° an average of about 68° F., and in latitude 50° an average of 43° F.

But we soon find, on examining a map of the world with the mean annual isotherms marked (Map 6), that these isotherms [1] do not correspond exactly with the parallels of latitude, as they would if the surface air temperature depended on geographical position or latitude alone. Thus the yearly isotherm of 60° F. in the northern hemisphere passes through the middle of the United States, over the Atlantic, and through the southern part of the mainland of Europe, crossing and recrossing the fortieth parallel of latitude several times. The isotherm of 50° F. passes through Vancouver, the south portion of the Canadian lakes, rises in the Atlantic to pass through the middle of the British Isles, and then gradually

[1] It must be remembered that isotherms are constructed to refer to temperature at the sea-level, and that to find the temperature of a place at some elevation 1 degree must be deducted for every 300 feet above sea-level.

ISOTHERMS FOR THE YEAR.



Longmans & Co. London, New York, & Bombay.

Walker & Boutall sc

MAP 6.

sinks through Eurasia. The isotherm of 40° F. shows that the west side of Canada is warmer than the east, that in Labrador there is a mean temperature 20° less than in the same latitude of North Britain. Note how the isotherms of 40°, 30°, and 20° are pushed northwards in the Atlantic and brought southwards again in Eurasia. Note also that in the southern hemisphere, where there is a greater proportion of water to land than in the northern hemisphere, the course of the yearly isotherms is not so irregular as those in northern latitudes. (Refer to Maps 1, 2, 6.)

Latitude, or geographical position, not only has great influence in determining the **mean annual temperature** of a place on the earth's surface, but it has an important effect on the **annual range of temperature,** or the difference between the mean temperature of July and January, to take the hottest and coldest months of the year. Owing to the different aspect presented by the earth to the sun in different parts of its orbit round the sun, the greater is the difference between the lengths of day and night during the course of the seasons (Par. 6); and as places receive heat during the day, when the sun shines, and lose it by radiation during the night, the farther we go from the equator the greater is the difference between the amount of heat received in summer and that received in winter. At the equator the days and nights are always equal, and at 15° north or south the greatest difference is scarcely an hour, so that in equatorial regions there is no real division into summer and winter, but greater uniformity of temperature. But beyond this limit every increase of latitude shows an increasing difference between the total quantity of heat received in summer and that received in winter, as illustrated below :—

	15° to 25°	25° to 35°	35° to 45°	45° to 55°	55° to 65°	65° to 75°	75° to 85°
Quantity of summer heat .	96	88	76	61	43	29	84
Quantity of winter heat . .	70	55	33	27	10	3	0

We can now understand why the 'range of temperature' in the Temperate and Polar zones is great, increasing, speaking broadly, as the latitude increases (*see* Maps 11 and 12, July Isotherms and January Isotherms), but modified by other causes. The range of temperature is an important element of climate, for it has great effect on both animal and vegetable life. Illustrations of increasing range of temperature with increase of latitude are furnished by the following figures and the diagram on page 90 :—

	Latitude.	Range.
Paramaribo, in Dutch Guiana .	5° 50′ N.	4°
Key West, in Florida . . .	24° 33′ N.	14°
Lisbon, in Portugal . . .	38° 42′ N.	21°
Portland, in Maine . . .	43° 40′ N.	47°
Dublin, in Ireland . . .	53° 20′ N.	23°
Moscow, in Central Russia . .	55° 75′ N.	49°
York Factory, on Hudson Bay .	57° 7′ N.	40°
Yakutsk, in Siberia (interior) . .	62° 2′ N.	105°
Reikjavik (Iceland) . . .	64° 8′ N.	24°

From the above figures and an examination of the course of the January and July isotherms it is evident that, although latitude is the main factor, other causes besides latitude affect not only the mean annual temperature but the range of temperature. Were the earth covered entirely with water, or entirely with land of uniform height, latitude alone would regulate temperature and other atmospheric conditions; but the unequal distribution of land and water brings into action, as modifying influences, the different heat properties of land and water, the effects of ocean currents of warm and cold water, and the effects of the prevailing winds. Variations of **altitude** lead to what may be called vertical climates. It is plain, also, that places may have the same mean yearly temperature but very different summer and winter temperatures, *i.e.* a different range of temperature. This is the case with New York, Dublin, London, and Sebastopol, the mean of all which is a little over 50° F.

60. **Influence of the Sea on Climate.**—A great extent of water surface tends to equalise temperature, and the sea, therefore, acts as a powerful modifying cause on climate. The water surface is more slowly heated than the land surface, and more slowly cooled than the land. In winter it slowly gives up the warmth stored up in summer, while in summer the cool breezes from it mitigate the heat of the land near it. Hence we find that the annual range of temperature of land near the sea is much less than that of inland districts. The different heat properties of land and water give rise to three classes of climate—**oceanic, insular,** and **continental.**

Oceanic climates are those which are regulated entirely by the sea at the given place. They are only to be found in the open sea or on small islands. They show for the same latitudes the least differences between the mean temperatures of the different hours of the day and the different months of the year. Some of the island groups in the Pacific, even within the Torrid Zone, enjoy a most equable climate, the thermometer not varying more than 5 or 6 degrees during the twelve months. This is due to ever-blowing breezes from the sea,

the surface temperature of which in the tropics shows but little variation throughout the year.

Insular or Coast climates are those in which the annual range of

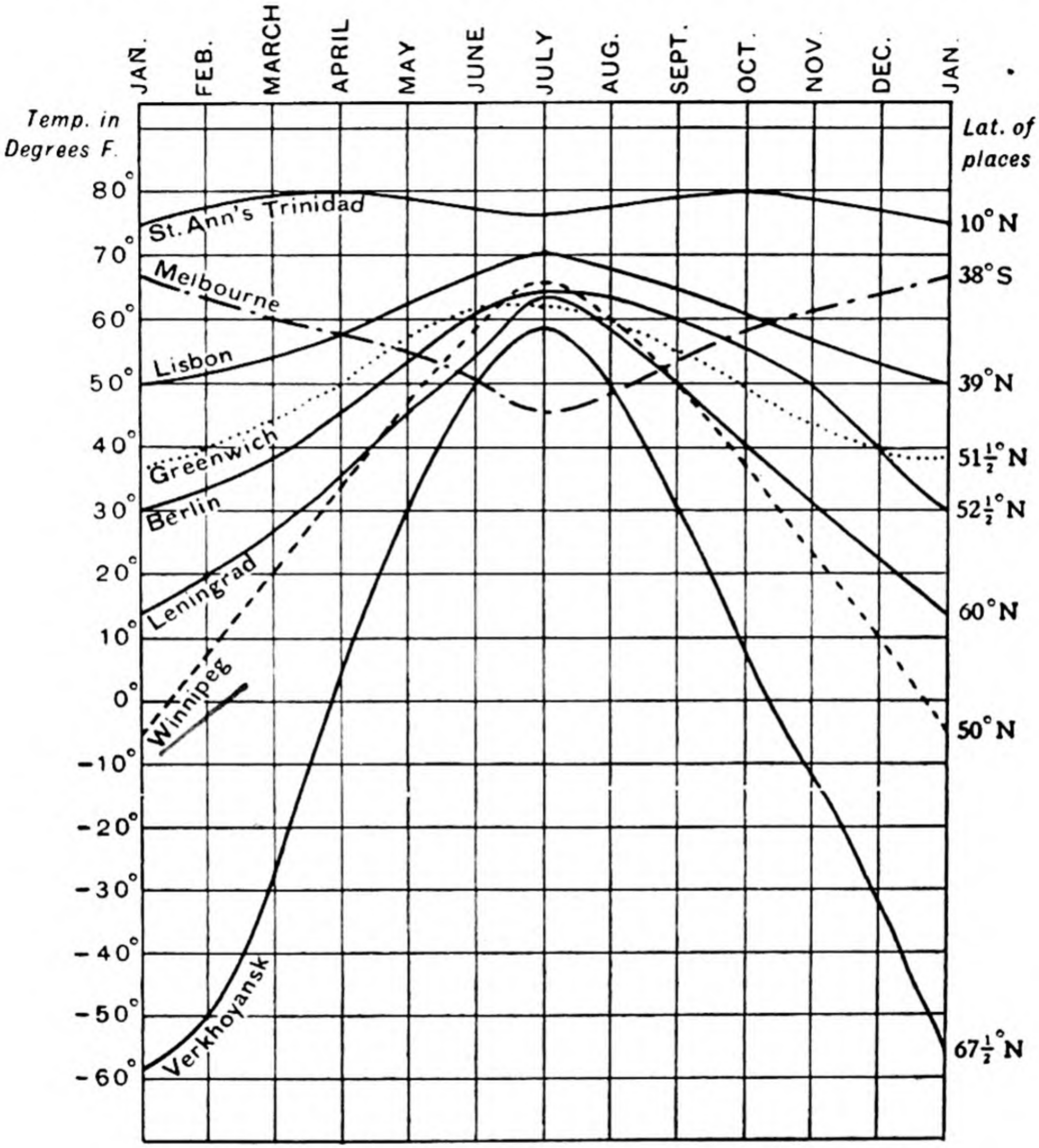


FIG. 63.—CURVES OF ANNUAL TEMPERATURE,

formed by joining the points indicating the mean monthly temperatures, and showing how the range of temperature is affected by latitude, distance from the sea, ocean currents, etc. (*Account for each curve.*)

temperature is small because the presence of the ocean diminishes the heat of the summer and the cold of winter. The yearly range seldom exceeds 30° F.

Continental or Land climates are those found in inland parts of

extended land surfaces, and in which there is a great range of temperature from summer to winter. The Maps of the Isotherms show the suitability of the term.

Great Britain and New Zealand are examples of insular climates, the summers not having the intense heat, nor the winters the great cold, that inland districts in the same latitude have. As an example of a continental climate we may cite that of Central Russia. Edinburgh and Moscow are in nearly the same latitude. The mean summer and winter temperatures of Edinburgh are 57° F. and 38° F. respectively; of Moscow, the temperatures are at the same seasons 64° and 15°. Thus there is a difference of range of only 19° at Edinburgh, but of 49° at Moscow. The freedom from the great extremes of Moscow gives to Edinburgh a great advantage. This influence of the sea and other large bodies of water has been put into the following statement by Dr. Haughton:—'Large masses of land anywhere increase the range of annual temperature; and large masses of water anywhere diminish the range of annual temperature.' The inspection of the Maps on which the January and July Isotherms are laid down for every 10 degrees furnishes instructive proof of this statement, as well as of other causes that operate in the distribution of temperature. Compare, for example, the position of the isothermal line of 60 degrees in the Atlantic Ocean, and in the Old World, during these two months; or compare the temperature of a point in mid-Atlantic and in Central Asia at these periods. Near Yakutsk in Siberia (see Map 6) there is a small district with the enormous range of over 100° F. At Yakutsk itself there is a temperature of 65·8° in its warmest month; while in the coldest the temperature is −44·9°, or 76·9° below freezing-point. But the influence of the sea is also exerted by mean of *currents*. The cold Arctic current that flows from the north past the coast of Labrador accounts not only for the fogs so prevalent, but also for the great coldness of the country when compared with British Columbia and with the countries on the opposite coast of the Atlantic, that are washed by the warm waters drifted from the Gulf Stream. These warm drift-waters, combined with the south-westerly winds, drive the isotherms northwards (*see* Maps), and render the western coasts of Great Britain far more temperate than they would otherwise be, raising the winter temperature several degrees. Its influence is exerted not only by the waters that strike the shore, but more effectively by the winds that blow from its surface. In a similar way the Kuro-Siwo current keeps Vancouver an open port when Montreal, farther south, but uninfluenced by winds from a warm current, is ice-bound. (*See* Par. 40.)

61. **Influence of Prevailing Winds.**—Winds are one of the most influential of the causes affecting climate. Being warm or cold, wet or dry, according to the district in which they have their origin, and according to the nature of the surface, sea or land, over which they have traversed, it is plain that the prevailing winds determine to a large extent both temperature and rainfall (*see* Par. 28). Over a warm sea-current the air is moist and warm; over a cold current the air has little moisture and is cold. The south-westerly winds that come across the wide Atlantic and strike the shores of Britain and North-western Europe bring warmth and moisture with them. The vapours condensed on the mountains which run along the western sides of the British Islands and the Scandinavian peninsula fall to the earth in heavy showers of rain. During this condensation a large quantity

of latent heat is set free to raise the temperature of the air. The importance of rainfall in conveying heat will be seen from the fact that one gallon of rainfall gives out latent heat sufficient to melt seventy-five pounds of ice. Dr. Haughton calculates that the amount of rainfall on the west coast of Ireland, 45 inches per annum, contributes nearly half as much heat to that district as that furnished by the direct influence of the sun. As an example of the lowering effect on temperature of a cold wind, attention may be called to the Southern States of North America, where during a part of the winter northerly blasts from the higher latitudes of that continent often produce winters of excessive severity. Generally speaking, where the prevailing winds are westerly, as in the northern hemisphere, and where currents of warm water are flowing in the same direction from the equator, the cold of winter is greatly mitigated, as is shown by the isotherms bending towards the pole. On the east coasts of Asia and America, however, the prevailing winds are northerly and cold, so that there is a great difference between the summer and winter temperatures. Thus it happens that the *west* coasts of the great continents enjoy an insular climate, while the *east* coasts and the inland districts endure the more trying continental climate. (*See* 'Water-vapour,' p. 26.)

We can now understand why it is said that winds and ocean currents can carry off the heat given by the sun to the tropics and give it out again in temperate zones.

62. **Effects of Elevation on Climate.**—As we ascend from the level of the sea to higher altitudes there is a gradual decrease in the temperature of the air—a fall of 1° F. for every 300 feet of ascent. What is the cause of this? Consider how air is warmed. The sun's luminous rays pass through the atmosphere, heating its various layers but little, and then, striking the earth, are absorbed. The warm earth then radiates outwards the heat thus absorbed from the sun, and these non-luminous heat rays are readily absorbed by the water-vapour and dust-motes in the dense air near the surface of the earth, and this air is also warmed by contact with the warmed ground. Now, the higher we rise in the atmosphere the rarer or thinner does the air become, and the less water-vapour and dust does it contain. Therefore, the higher parts of the atmosphere are colder than the lower layers, because the higher we ascend the less dense is the air, the less is the quantity of vapour and dust-motes, so that there are fewer molecules to absorb the heat rays radiated from the earth. In other words, the air is not much warmed directly by the sun, but chiefly by the earth, and the higher and thinner layers of the atmosphere are thus really farther from the chief source of heat.

'Thus it happens that, in ascending a mountain from the sea-level to the limit of perpetual snow, we pass through the

same series of climates, so far as temperature is concerned, which we should do by travelling from the same station to the polar regions of the globe; and in a country where great differences of level exist we find every variety of climate, arranged in zones according to altitude, and characterised by the vegetable productions appropriate to their habitual temperatures.'

We can now understand why the mean annual temperature of Quito, situated nearly on the equator at an altitude of 9,300 feet, on the Andes, is only 56° F. (the mean temperature at sea-level in lat. 0° is about 80° F.), why European residents in India retire to Simla, Darjeeling, and other hill-stations on the slopes of the Himalayas during the hot season, and why such peaks as Kilimanjaro (20,000 feet), Kenia (18,500 feet), and Ruwenzori (16,600 feet), close to the equator in tropical Africa, have their tops covered with everlasting snow.

We can also see why inland tablelands not only have a lower mean temperature than places at the sea-level in the same latitude, but why they have a great range of temperature. For the rarer air permits the ground of highlands to become hotter when exposed to the sun (by day or in summer) than does the denser air over lowlands; while, on the other hand, when not exposed to the sun (at night or in winter), the same air allows radiation to go on more rapidly from the high ground than from the ground near sea-level. Hence plateaux or tablelands have great diurnal and seasonal variations of temperature. Thus Madrid, situated on the central plateau of Spain, 2,150 feet high, has a mean January temperature of about 40° F. and a mean July temperature of 76° F., or range of 36°, while the range at Lisbon is only about 20°. Other plateaux, as that of Khorassan in Persia, and Tibet in Central Asia, show a similar wide range of temperature, with a much lower average temperature than lowlands in the same latitude.

As an illustration of the increase of rainfall with elevation owing to mountains acting as condensers of moisture, it may be stated that on the summit of Ben Nevis, 4,406 feet above the sea, the annual rainfall is 129·5 inches, while below, at Fort William, it is only 77 inches (*see* fig. 33).

63. **Minor Causes Influencing Climate.**—Among other influences that affect climate we find :—

(1) **The Direction of the Mountain Chains.**—Mountain chains that run at right angles to the prevailing winds have a moist side on the windward slope and a dry side on the leeward slope, for the air currents are compelled to ascend in crossing

the range, and, being cooled by ascent and expansion, deposit their moisture on the windward side. Thus, in the Torrid Zone easterly winds prevail, and the east slope of the mountain chains is the wet slope. An example is the Brazilian slope of the Andes, which receives the rain of the south-east trades (the water filling the great tributaries of the Amazon), while the leeward side of the chain is quite dry.

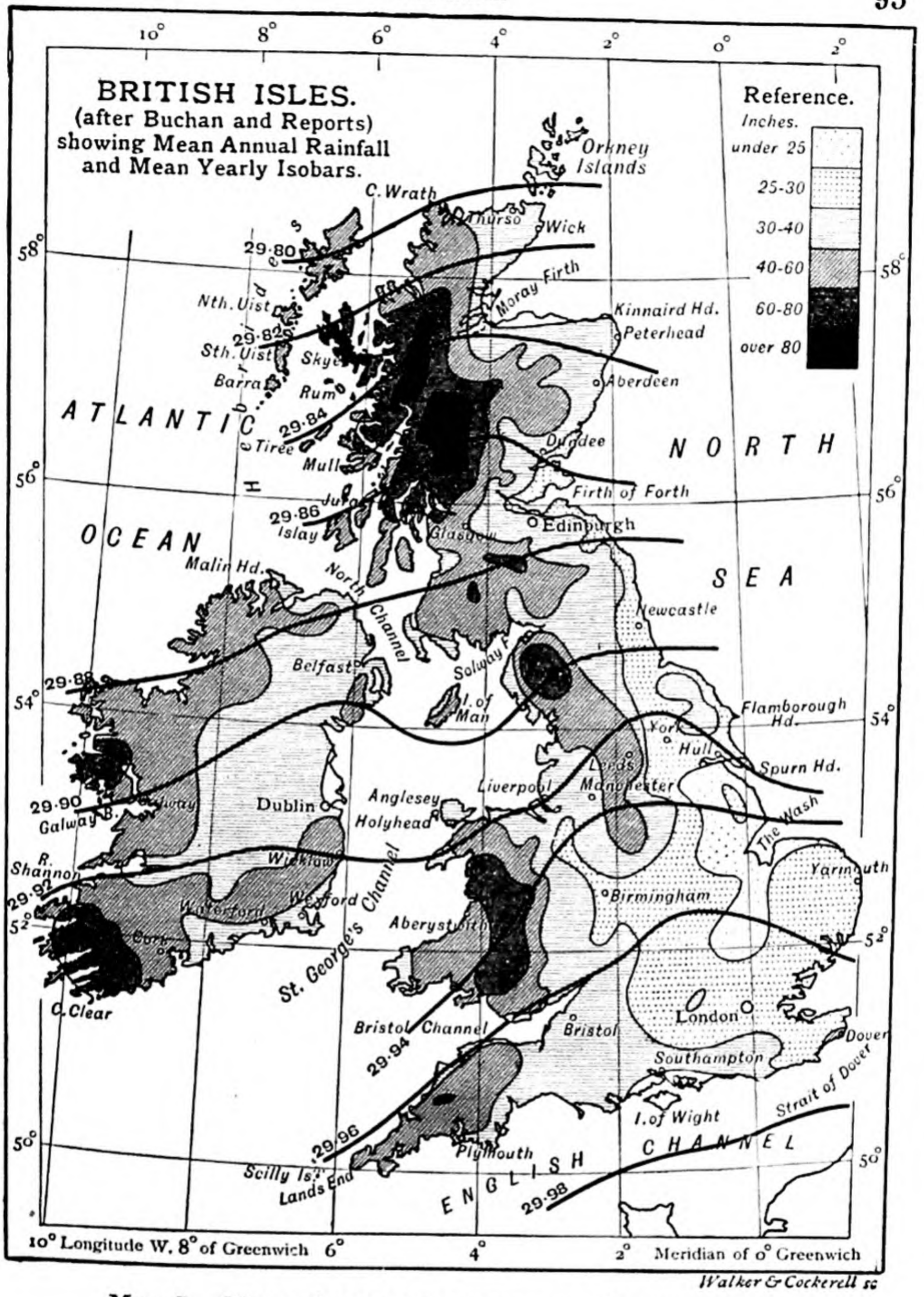
In higher latitudes the west side of mountain chains receives the greatest rainfall and has a moist climate, as in Great Britain and the Andes of Southern Chile, while the climate on the east is much drier.

Mountains also afford shelter from cold winds. Thus the Alps protect the plains of North Italy from the cold northerly winds sometimes blowing across Germany (*see also* p. 101).

(2) **The Slope of the Ground.**—(The word *climate* comes from a Greek word, *klimata*, slopes or inclinations, and referred originally to the apparent slope of the earth towards the pole, but its original meaning is now extended.) Here, by slope we mean the angle of inclination of a district towards the equator, *i.e.*, towards the sun; and it is clear that a portion of land sloping towards the south in the northern hemisphere receives the sun's rays more perpendicularly than land sloping north. Hence the southern sides of the Alps in Italy are clothed with vegetation to a far greater height than the northern sides, and the same is true of other mountains. In England fruits grow best on a 'southern aspect,' in New Zealand on a 'northern aspect.'

(3) **The Nature of the Soil** affects climate through the different heat-absorbing and heat-radiating powers of various rocks. A sandy waste like the Sahara absorbs a great quantity of heat during the day and radiates rapidly during the night, while wet and marshy grounds lower the mean temperature by conducting the heat absorbed downwards. Cultivation and drainage thus tend to make a climate warmer and more salubrious, as has happened in the Fen district of England; though great destruction of forests may lower the rainfall too much, since forests attract and hold moisture. Note that the results of drainage and forest-clearing are effects of **human agency.**

63*a*. Map 7, on page 95, illustrates several points in regard to the climate of the British Isles. We see, for example, how much greater the rainfall is on the west than on the east, how much greater it is in mountainous districts than on the low-land plains. The reasons have already been given. We find



MAP 7.—MEAN ANNUAL RAINFALL OF BRITISH ISLES.

also from the yearly isotherms sloping down towards the east that it is warmer on the west than on the east. On the Map (p. 146) showing the January isotherms this is still more apparent, for the January isotherms run almost *from north to*

south, and it is then several degrees colder on the east coast of England than on the west. This is owing to the fact that the warm west winds from the Atlantic soon get robbed of their warmth and moisture as they pass inland over the cold ground of winter. The isotherms for July run *west and east* almost at right angles to the January isotherms, for in July the land has become warmed by the summer sun, and is, in fact, hotter than the sea, from which the west winds come, so that the July isotherms, indeed, rise towards the east, and it is then as warm in Durham as in South Wales.

The various causes that modify climate, especially those that modify the effect of latitude, are well illustrated in North America. Sitka in Alaska, and Nain in Labrador, are both situated on the sea coast about 57° N. lat. The mean yearly temperature of Sitka is 43·3° F., and that of Nain 21·7° F., while the winter and summer temperatures of Sitka are 31° F. and 56° F. respectively, those of Nain being 8° F. and 48° F. The causes of these differences on the east and west sides are to be found in the character of the ocean currents and prevailing winds. On the Pacific coast is the return portion of the warm Kuro-Siwo, or Japan Current, with the moist warm winds that blow from it; on the Labrador coast is a cold Arctic current and cold northerly winds.

Again, consider the following figures :—

		New Westminster.	Winnipeg.	Toronto.	Quebec.	St. John.
Mean Temp.	Jan.	36·4° F.	0·7° F.	21·6° F.	9·1° F.	18·5° F.
	July	58·5° F.	66·1° F.	68·2° F.	66·5° F.	60·3° F.
	Year	48·1° F.	32·7° F.	43·8° F.	38·7° F.	40·4° F.
Rainfall		59·2 in.	15·2 in.	23·2 in.	25·1 in.	40·7 in.
Snowfall		52·2 in.	49·2 in.	69·0 in.	159·7 in.	96·5 in.

These various places differ but little in latitude, and yet exhibit great differences of climate as regards temperature and rainfall. The differences on the east and west coasts are mainly due to the causes given for Sitka and Nain, though St. John, in New Brunswick, is influenced during part of the year by warm breezes from the Atlantic. Winnipeg and Quebec, and, indeed, all places in the interior of Southern Canada, have the hot summer and cold winter of a 'continental climate,' while the shores of British Columbia and South-eastern Canada show the equalising effects of proximity to the sea. Even Toronto, in the neighbourhood of the Great Lakes, has its 'range of temperature' thus lessened. The greater rainfall (10 inches of snow equal 1 inch of rain) of New Westminster and British Columbia generally is due to the warm moist winds from the Pacific, while in the interior, east of the Rocky Mountains, which deprive these winds of their remaining moisture, the climate is dry, with a severe winter. It is the dryness of the cold winter air that enables the inhabitants to endure it so easily. (*See also* Glossary, 'Climatic Zones,' and Questions 179, 189.)

64. Influence of Climate on Vegetable and Animal Life.—The productions of a country will depend to a large extent on

its climate, for certain districts are best suited to certain plants and animals. Heat and moisture are the conditions most favourable to vegetation, and hence the most luxuriant vegetation is found in the dense forests of the moister parts of the Torrid Zone. Here we find the various kinds of palm, the banana, the yam, the bamboo, and such plants as require hothouse cultivation in England. Other plants require less heat and flourish in sub-tropical regions. Such are the vine, rice, tea, the fig and tobacco. As we pass towards the poles the variety of vegetation diminishes. The forests soon contain little but pines and firs, until on the borders of the Arctic Sea nothing but lichens and mosses flourish. Dry and arid districts have their peculiar vegetable life, adapted to periods of drought. Thus, in many hot and dry regions the trees have thick leathery leaves with fleshy stems and prickles, like the cactus-plants of Mexico and the euphorbias of Africa, while in steppes there are grasses and lily-like plants with thick matted roots and large underground bulbs. Some plants, like cotton, sugar, the rubber-plant, and the vine, are very sensitive to changes of temperature, and thus the vegetable production of a district may be determined by the annual range of temperature. The character of the summer and winter is therefore important. Thus, the heat of summer in England is not sufficient to enable us to grow grapes and tomatoes out of doors, as in South Germany; but we can grow many perennial plants—as roses—in our gardens that require protection in the cold German winter. Elevation above the sea has the same effect as latitude, and in India we may pass from the mango, palm, and sugar of the low plain to the vines and melons of the hill slopes, to the apples and barley of higher slopes, and, finally, to the few shrubs on the edge of the eternal snow.

Animals show variations to some extent similar to those of plants (compare the fur-bearing animals of the polar regions with the almost bare-skinned animals of the tropics), but they are better able to adapt themselves to new external conditions. But neither in the case of plants nor of animals does latitude or climate entirely account for the kind of life that flourishes in a region, for, to some extent, every region of the globe that is separated from surrounding regions by great physical barriers, as the sea, mountain chains, or deserts, differs from these surrounding regions in its flora and fauna (Chap. VIII.). (For the effect of climate on **man**, *see* Par. 70.)

64*a*. **Climatic Regions.**—The world can be divided into twelve major regions on the basis of climate.

1. Equatorial or Hot, Wet Climate.	Climates of Low Latitudes or the Tropical Zone.
2. Tropical or Sudan Type of Climate.	
3. Monsoon or Summer Rain Climate.	
4. Hot Desert or Sahara Type of Climate.	
5. Temperate Desert or Iran Type of Climate.	Climates of Mid-Latitudes or the Temperate Zone.[1]
6. Mediterranean or Winter Rain Climate.	
7. Warm Temperate East Coast Types of Climate.	
8. Cool Temperate Oceanic or Rain at all Seasons Climate.	
9. Cool Temperate Continental or Grassland Climate.	
10. Cold Temperate Climate.	
11. Arctic or Cold Desert Climate.	
12. Alpine Climate.	

(1) *The Equatorial Climate, or Climate of the Hot, Wet Evergreen Forests.*—This type is found as a belt stretching about 5° on each side of the equator. The temperature is high all the year round but does not vary very much ; an average for the whole year is about 80°. Rains fall nearly all the year, so that the air is always hot and moist and the climate as a whole unhealthy. The rains are convectional rains. Owing to the great heat there is much evaporation. The water vapour rises to the upper part of the atmosphere and is cooled and so falls as rain. Very often evaporation takes place during the morning and the rain falls in the afternoon, accompanied by thunderstorms. Though rain falls throughout the year there are typically two seasons rainier than the rest of the year. The Amazon and Congo basins are typical areas having this climate. Islands near the equator—the East and West Indies—have a similar climate, and so has the Malay Peninsula and New Guinea. Parts of Ceylon and the Guinea coast in Africa have a climate which is very nearly of this type.

(2) *The Tropical Climate, or Climate of the Savana or Tropical Grassland.*—This climate is found on either side of the equatorial belt, and is well developed in Africa. As usual, 'rain follows the sun,' and so the heaviest rainfall occurs soon after the sun has been shining vertically, whilst the dry season occurs in the colder part of the year. This type of climate is found in the Sudan (Africa), and so is often called the Sudan type. The Orinoco Basin and the Brazilian Highlands in South America have this climate.

(3) *The Monsoon Climate.*—The Monsoon Climate is very

[1] They occur in the 'Temperate Zone' but are often climates of great extremes.

similar to the Tropical Climate, but the rainfall is caused in a different way. This climate is found typically in India and along the north-western coast of Australia. There is the cool season with little rain, lasting in India and Burma from about November to February; then the temperature begins to get higher, and there is the hot season from March to June. The rains break in June and last till October. Nearly all rain falls in the latter period. If these are the seasons in a monsoon area of the Northern Hemisphere, how would they be different in the Southern Hemisphere? Another name for the Monsoon Climate is the Summer Rains Climate, for the rain falls in the summer of the year. The summer would otherwise be very hot indeed, but the rains make it cooler. The Monsoon Climate occurs around the Indian Ocean, especially in India, Burma, North-Western Australia, and Abyssinia in Africa. There are small regions in North-Western South America which have a monsoon rainfall.

(4–5) *The Climates of the Great Deserts.*—Passing from the region of the Tropical or Monsoon Climates towards the poles we find regions which are very hot and dry—so dry that scarcely any plants can grow. These regions lie mainly in the high-pressure belts just outside the Tropics. The Trade Winds blow away from them towards the equator, the Anti-Trade Winds blow away from them towards the poles, and there are no winds which bring rain into the regions. Some of the regions are dry too, because, like the centre of Asia, they are very, very far from the sea. There is very little rain and no clouds, so that the sun's rays strike down fiercely on to the ground and make the days very hot indeed. The highest temperatures in the world are found in these regions. But at night the ground loses its heat very quickly, and so the nights are cool. We may divide these deserts into two groups:

(*a*) The Hot Deserts, occupying lowlands along the Tropics of Cancer and Capricorn. Examples are the Sahara Desert, the Desert of Arabia, and the Great Indian Desert. In the Southern Hemisphere there are deserts in Australia, South Africa (Kalahari), and South America (Atacama).

(*b*) The Temperate Deserts, usually found on plateaux outside the Tropics. They are much colder in the cold season, and may be covered with snow. Examples are the desert of Iran or Persia, the deserts of Gobi or Shamo, and Colorado in North America.

(6) *Mediterranean Climate.*—As the sun moves north and south of the equator during the year, so the main wind belts

of the world swing with it. There are parts of the earth between latitudes 30° and 45° which in summer are in the northern part of the Trade Wind Belt, and so are hot and dry like the deserts which join them on the side nearer the equator. In winter, however, these regions come under the belt of westerly winds, and so enjoy moist, mild winters. In other words, this is the Winter Rain Climate. Contrast it with the Monsoon or Summer Rain Climate, but remember that the Monsoon Climate is, on the whole, a much hotter one. The Mediterranean Climate is so called because it is found all round the Mediterranean Sea, but it is also found on the western sides of North and South America, South Africa, and South Australia (*e.g.* Perth, Adelaide and Melbourne).

(7) *Warm Temperate East Coast Climate.*—The Mediterranean Climate is found in regions on the western sides of the continents, but on the eastern sides, just outside the Tropics, there are sometimes regions having a warm, moist summer and a cool, sometimes dry, winter. You will see this is very like the Monsoon Climate, but the temperature throughout the year is less as the regions lie outside the Tropics. China and Eastern Australia, South-Eastern U.S.A., and the coastal regions of Natal are examples, but there is a very considerable difference between China, with very cold winters, and the other regions.

(8) *Cool Temperate Oceanic Climate.*—You learnt that the Mediterranean regions feel the effect of the rain-bearing westerly (Anti-Trade) winds during the winter. We come next to those regions which are in the westerly wind belt during the whole year. They have rain all the year round, but compared with rain in tropical regions it is much less. The winters are mild and the summers cool. This is the climate of North-Western Europe (including the British Isles), Western Canada, Southern Chile, Tasmania, and New Zealand. On the east of the continents (New England and Manchuria) the winters are much colder.

(9) *Temperate Continental or Temperate Grassland Climate.*—Regions having this climate lie mostly in the same belts as the last—in the westerly wind region—but they are far from the ocean and do not feel the moderating effects of its presence. Consequently the summers are very hot and the winters are very cold—a typical 'Continental Climate.' Rain falls mostly in spring and early summer, but it is not heavy. It comes mainly as light showers. In winter a little snow may fall. You will learn later of the great and very important

grassland regions of the world where this climate occurs—the prairies of Central Canada, the steppes of South Russia and South Siberia. Although this type of climate, sometimes called the Riverina type, is found in Australia, South America (Pampas), and South Africa, the extremes of temperature are much less than in the heart of Asia or North America, and snow is rare.

(10) *Cold Temperate Climate, or Climate of the Coniferous Forests.*—The Cool Temperate Oceanic Climate passes gradually into a colder climate where much of the moisture falls as snow and not as rain. This is the region of the coniferous forests, and occurs as a great belt across North America, Northern Europe, and Northern Asia.

(11) *Arctic or Cold Desert Climate.*—Here the winters are very long and very cold, and there is only a very short, sharp summer. This climate occurs in the frigid zones—inside the Arctic and Antarctic circles.

(12) *Alpine Climate.*—The effect of climbing up a mountain is very like going a great distance towards the poles. The climate changes as we ascend and gets colder and colder. Near the tops of high mountains it is very cold and, as you know, there is perpetual snow above the 'snow-line.' But the climate just below the snow-line is not quite the same as in Arctic or Antarctic lands, because on the mountain-tops the air is very thin. So we have a special name for the climate found on high mountains—the 'Alpine' Climate, named after the great mountain chain of Europe, the Alps.

CHAPTER VIII

THE GEOGRAPHICAL DISTRIBUTION OF PLANTS AND ANIMALS

65. **Distribution of Plants.**—The whole assemblage of plants native or indigenous to a country or district is termed its **flora,** and the geographical range of plants is in great part, but not entirely, regulated by climate. Under certain conditions of heat and moisture certain plants thrive, and if removed to districts and soils where these conditions are much different they perish. Under corresponding conditions of soil and climate, however, transported plants will thrive almost as

well as in their native area or **habitat.** Thus the cinchona, whose bark yields quinine, is indigenous to the eastern sides of the Andes in tropical South America, but it has been introduced into and cultivated in India, Ceylon, and Java. The cereals, or corn plants, and the vine have been introduced into Australia, the potato was brought from America to Europe, etc.

65*a*. **The Vegetation Belts of the World and their Inhabitants.**—For each type of climate there is a characteristic vegetation, and the two in their turn control the animal-life, man and his activities. We will take the vegetation belts in the same order as the climates.

(1) *The Evergreen Equatorial Forests, or Selvas* (*Hot, Wet Forests*).—In the belt of equatorial rains, and even in monsoon lands where the rainfall is more than 80 inches in a year, the air and soil are always damp. The moisture and heat cause the growth of luxuriant trees, often of great size. All plants need light and air, and amid the dense, rank growth of the equatorial forest there is a constant struggle upwards to reach the light. The big trees grow tall and straight, with a crown of leaves at the top. Other plants reach the light by climbing up the trees—these are the lianes or woody climbers—and often grow to such a size as to kill the tree by which they climbed up. Other plants grow high up on the branches of the trees and reach the light that way. Thus the branches may be thickly clothed with ferns. In the tallest and densest equatorial forests the mass of leaves is so thick that no sunlight ever reaches the ground, and it is dark and gloomy. This is the case with many of the forests of the Amazon and Congo Basins. Other forests are not quite so thick, and a little sunlight may reach the ground. The forests of much of the East Indies are like that, and there we find rich growth of smaller plants (which we call undergrowth) on the ground. The trees of the equatorial forests are of very many different kinds, but nearly all of them have very hard wood. Much of the wood is very fine—like mahogany and ebony—but it is very difficult and expensive to cut down these great hard-wooded trees. Even the more easily reached evergreen forests are scarcely touched yet.

The equatorial forests are the home of the rubber trees, and rubber collecting is still an important industry in the Amazon forests of South America. But the most and best rubber is now obtained from plantations which man has made —on the fringes of the equatorial belt in Ceylon, Malaya,

East Indies, and Lower Burma. Another useful tree is the cinchona, whose bark yields the medicine quinine. The cocoa or cacao tree belongs to these regions too, and also the manioc plant. Near the sea, on sandy shores, we find the coconut palm everywhere. Its big seeds, the coconuts, float and are carried by ocean currents, so that the palm is found on nearly all tropical islands. In Africa the Guinea oil palm takes the place of the coconut palm.

Animals, like trees, must have light and air, and so we find

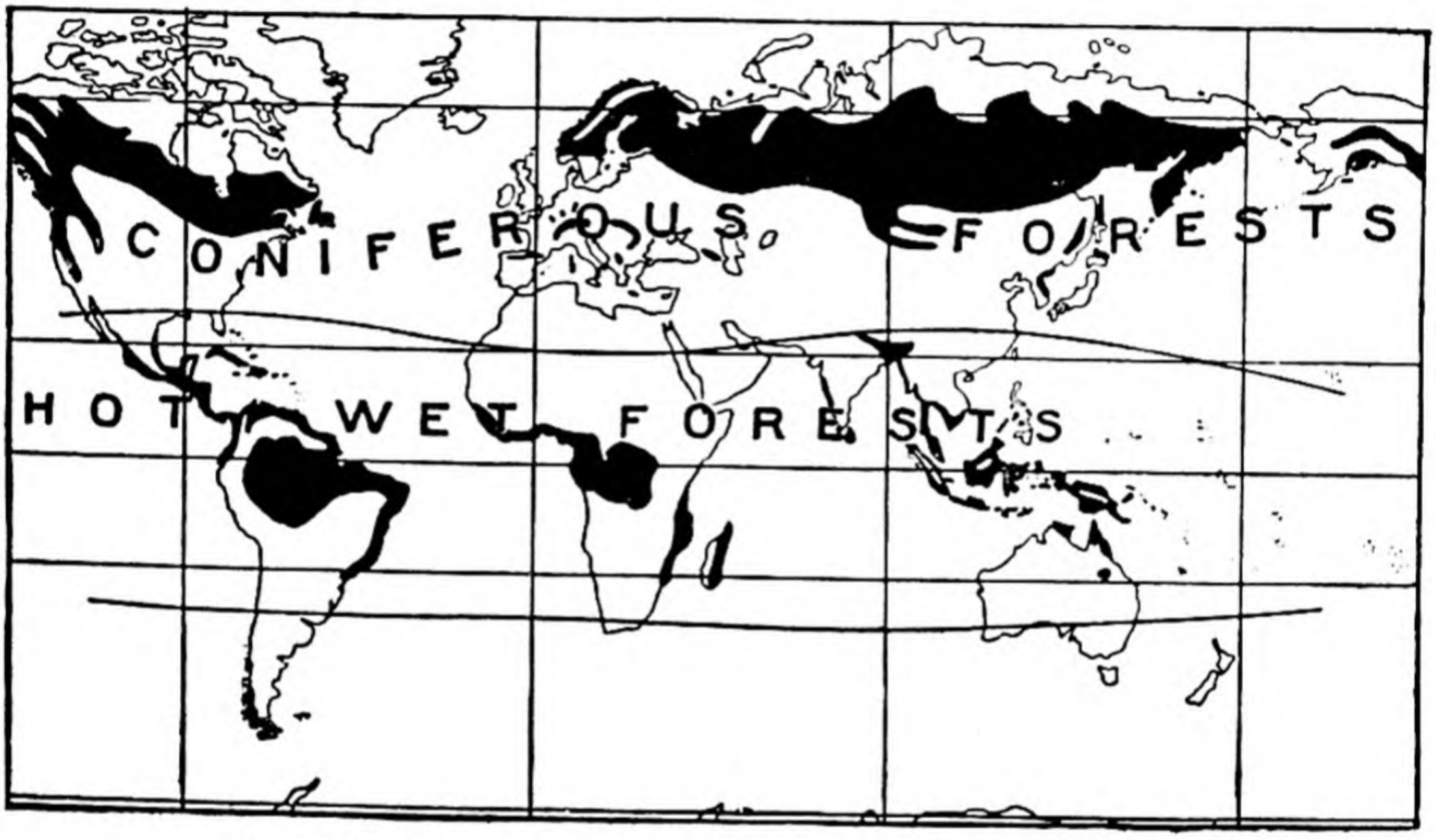


FIG. 64.—THE EVERGREEN FORESTS OF THE WORLD.

most of the inhabitants of the equatorial forests are adapted for climbing. The monkeys are typical. In the denser forests nearly all the animal-life is to be found in the treetops. There we find all sorts of animals specially adapted for climbing—tree-frogs and tree-lizards as well as birds, and a wealth of insect-life.

How is man to live in such forests? The hot, moist air is not good for his growth and development; it is never cold, so that little clothing is required. Many of the trees of the forest yield fruits fit for food. But it is very difficult to cut down the forest and carry on agriculture, for the forest grows up again very rapidly. So we find the equatorial forests are inhabited by very backward, uncivilised tribes; many of them, like the Pygmies of the Congo, are of very small size. They

wear very little clothing and often have no huts at all, or build small shelters in the trees. Some of them, like the natives of the Amazon Basin, are hunters and wanderers. They live mainly on the jungle fruits. The climate makes difficult, though far from impossible, any improvement in agriculture or the arts.

(2) *The Tropical Grasslands and Savanas.*—The characteristic vegetation of the tropical climate is a rich growth of tall grass with scattered trees. You have learnt of the large area of Africa which has a tropical climate. Nearly all this country is covered with savana. In South Africa and Rhodesia we refer to it as ' Bush Veld.' The grass springs up quickly during the rains, but later in the year is scorched by the sun, and the country is dry and brown during the hot season. Trees become more numerous as the rainfall increases. Many of the tropical grasslands have strong winds, and very much wind is bad for the growth of trees. We find many of the trees of the savana are umbrella-shaped, so that they expose only a narrow edge to the wind.

You have learnt that the animals of the equatorial forest are specially adapted for climbing—the monkeys, for example, escape from their enemies by their speed and cleverness in swinging from one tree to another. In the savana climbing animals would have few trees to climb, and so we find the animals are specially adapted to escape from their enemies by swiftness of flight. We really find two main groups of animals—the swift-footed grass-eating animals like the antelopes and giraffes, and the savage flesh-eating animals like the lion and tiger which live on them. Very often the grass-eating animals will be disturbed in the midst of a meal and have to run away. So we find many of them swallow their food very quickly, and then when they are quiet and at rest are able to chew it over again—chew the cud, as we say. You have all seen cows do this. Just as the savanas (*e.g.* in Africa) have supported vast herds of wild grass-eating animals, so man is able to raise great herds of cattle on the tropical grasslands. So we find the inhabitants of the grasslands are at first hunters hunting the wild animals, later they become pastoral peoples interested in the keeping of herds of cattle. Read what is said of life on the Temperate Grasslands. It is very similar. There are great stretches of these tropical grasslands in the north of Australia.

(3) *The Monsoon Lands.*—The natural vegetation of the monsoon lands is typically seen in India. The ground is

covered with forests which lose their leaves during the hot season. Trees require a great deal of water, which they drink in through their roots and lose by evaporation through their leaves. In the dry, hot weather it is necessary that the trees do not lose too much water. So in the monsoon forests the trees guard against this loss by shedding their leaves. When the rainfall is more than 40 inches the monsoon forests consist of fine large trees, of which teak and sal are familiar examples. But as the rainfall gets less and less the trees become smaller, and many of them are armed with thorns.

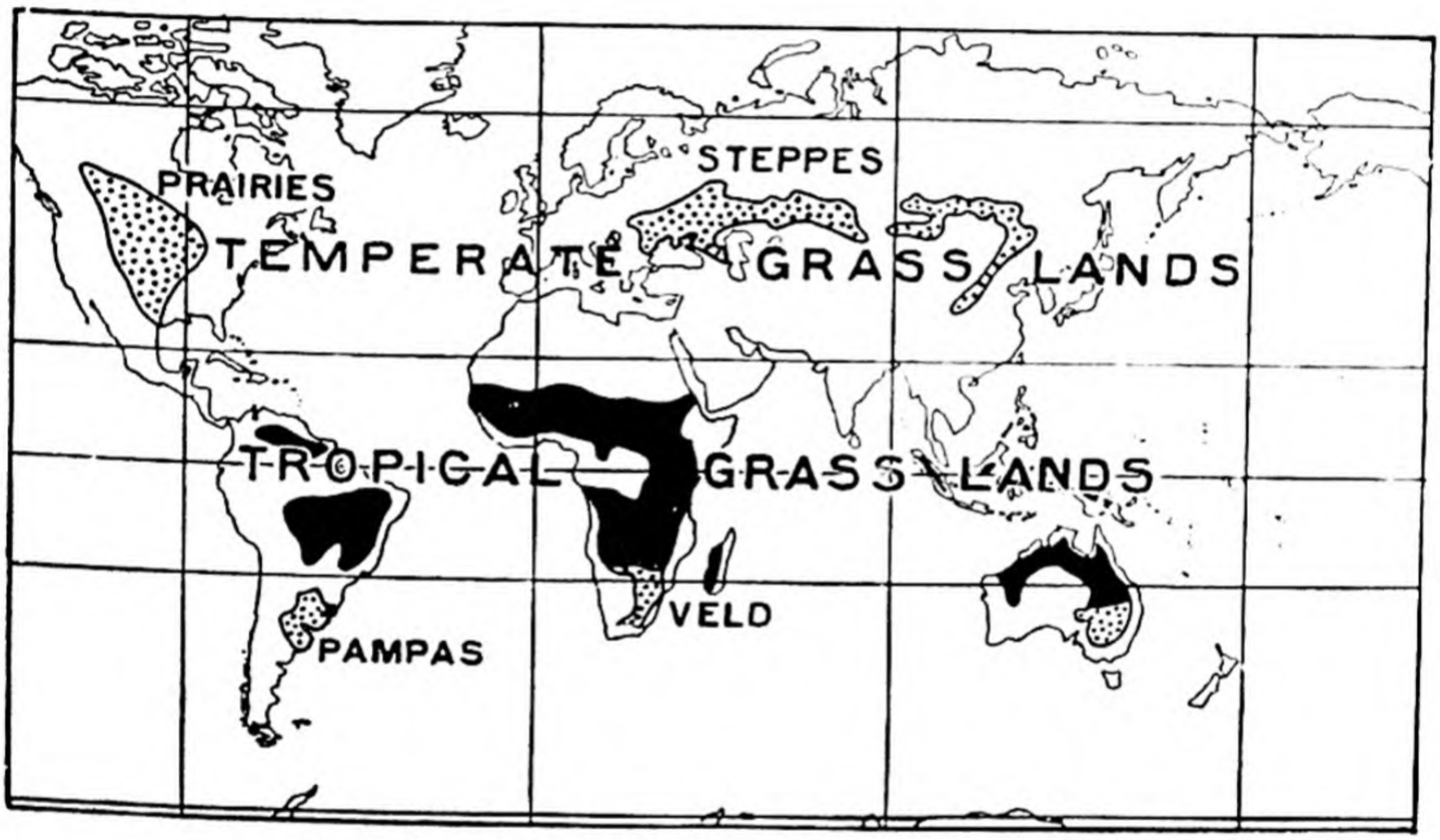


FIG. 65.—THE GRASSLANDS OF THE WORLD.
The tropical grasslands or savanas are shown in solid black, the temperate grasslands by dots.

The forest, as we say, passes into thorn forest and scrubland, and finally into desert with only a few scattered shrubs. Monsoon forest is not as thick as equatorial forest, and can more easily be cleared for agriculture. Many plants of great value to man flourish in the monsoon climate. There are timber trees, bamboos, various palms, fruit trees like the mango and bread fruit, as well as plantains and bananas. More important still are the cereals, rice in the wet lands and millet or sesamum in drier parts. On certain soils cotton flourishes; tea and coffee grow well on hill slopes. Maize can also be grown and wheat as a winter crop.

The monsoon climate is, then, very favourable to the growth of food crops. So we find most of the monsoon lands are very thickly populated. In some parts it is very easy to obtain sufficient food and the people get lazy, but if they do not let themselves get lazy there is great opportunity of becoming rich or learned, and so we find a high state of civilisation in many monsoon lands.

(4) *Tropical and Temperate Deserts.*—In talking about the monsoon lands we said that as the rainfall gets less the monsoon forest becomes poorer and poorer, passes first into scrubland

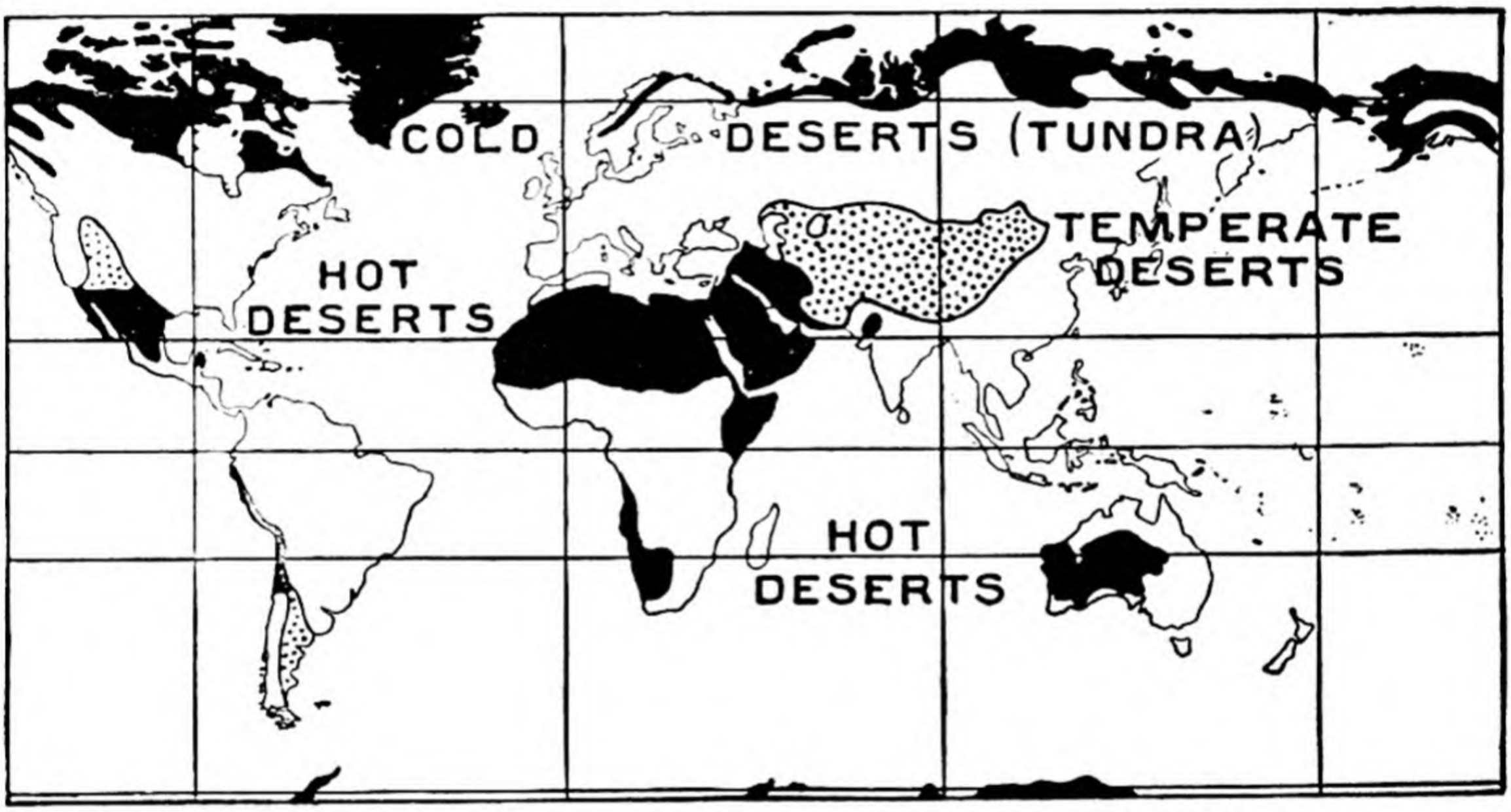


FIG. 66.—THE DESERTS AND SEMI-DESERTS OF THE WORLD.
Notice what a large part of the land surface is waste, desert land. Try to name each of the desert areas shown on this map.

and then into desert. In the same way grassland becomes poorer and poorer, and passes eventually into desert. Thus desert is sometimes very, very poor grassland, at other times very, very poor scrub or woodland. There are few deserts where absolutely *nothing* grows. We find desert plants have different means of storing water. Some of them have very, very long **roots** which go down to great depths and there reach water; many have fleshy stems and leaves in which they can store up water; many prevent the loss of moisture by covering their stems and leaves with a thin coating of wax; the Australian eucalypts do so by turning their leaves slant-

wise to the rays of the sun ; still others are armed with sharp spines and thorns which protect them from being eaten by animals.

Much of the vegetation in arid regions or 'semi-deserts' possesses such means of storing water, and is protected from animals in these ways.

Then we must not forget the fertile spots, called oases, in the middle of the deserts. Some of these oases consist merely of a clump of palms surrounding a small spring of water, but others are many hundreds of square miles in area and very fertile. The typical tree is the date-palm.

When we look at the animals of the desert we find there are only a few, and they usually have a dull brown colour which exactly matches the sand and prevents them from being seen. The most typical animal is the camel, which is able to go many days without water and which has a broad foot to prevent it from sinking into the sand.

There are two classes of inhabitants in the desert—the wanderers who move with their camels from place to place, and the settled population of the oases who devote themselves to growing cereals and rearing cattle, and especially to the cultivation of the date-palm. People living in the desert have little to see except the vast expanses of rocky and sandy waste. They must study the stars to guide them by night, and so we find that the desert has produced philosophical peoples—people who have plenty of time to think, and people learned in mathematics and the study of the stars. The wanderers live mainly in tents, but the dwellers in the oases build houses with thick stone walls—to keep them cool—and flat roofs, for there is no need to guard against rain.

(5) *Mediterranean Lands.*—In the Mediterranean climate, with its mild moist winter and hot dry summer, the plants grow mainly during the winter and have to protect themselves against loss of moisture during the hot dry summer. The vegetation of Mediterranean lands consists chiefly of small trees and shrubs, usually with small leathery leaves well adapted to withstand loss of moisture. Others, such as the olive, have leaves covered with silky hairs ; others, like the vine, have very long roots. The Mediterranean trees are remarkable for their fine, luscious fruit. The most important plant is perhaps the vine, whose fruit (grapes) is made into wine as well as being dried. Then there are well-known fruits as oranges, lemons, peaches, apricots, and pears ; nuts,

such as the almond, and many others. All of you know the tinned fruit which is sold all over Britain. Notice the labels of the tins. Much of it comes from the "Mediterranean"

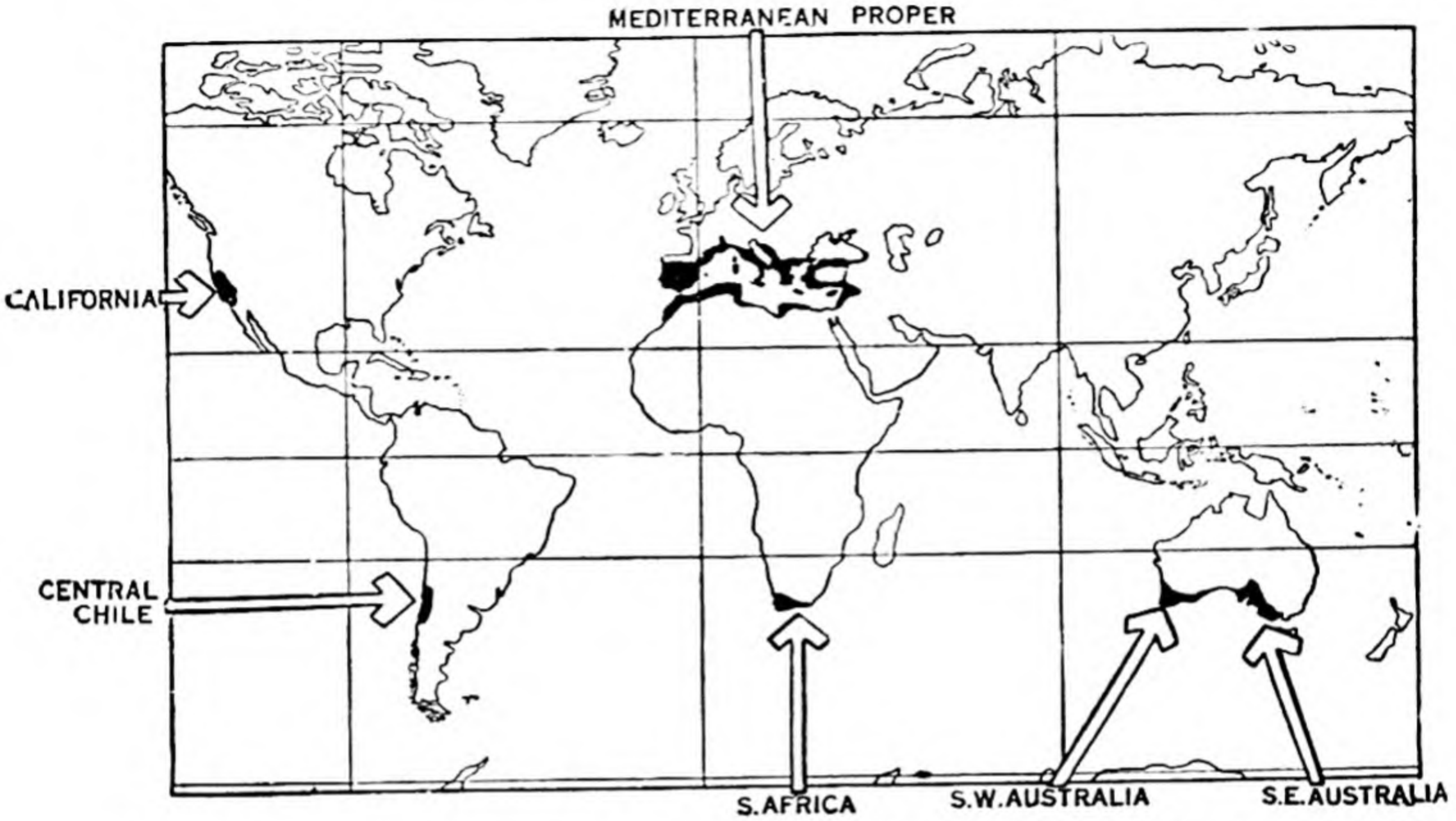


FIG. 67.—MAP OF THE WORLD, SHOWING THE MEDITERRANEAN REGIONS.

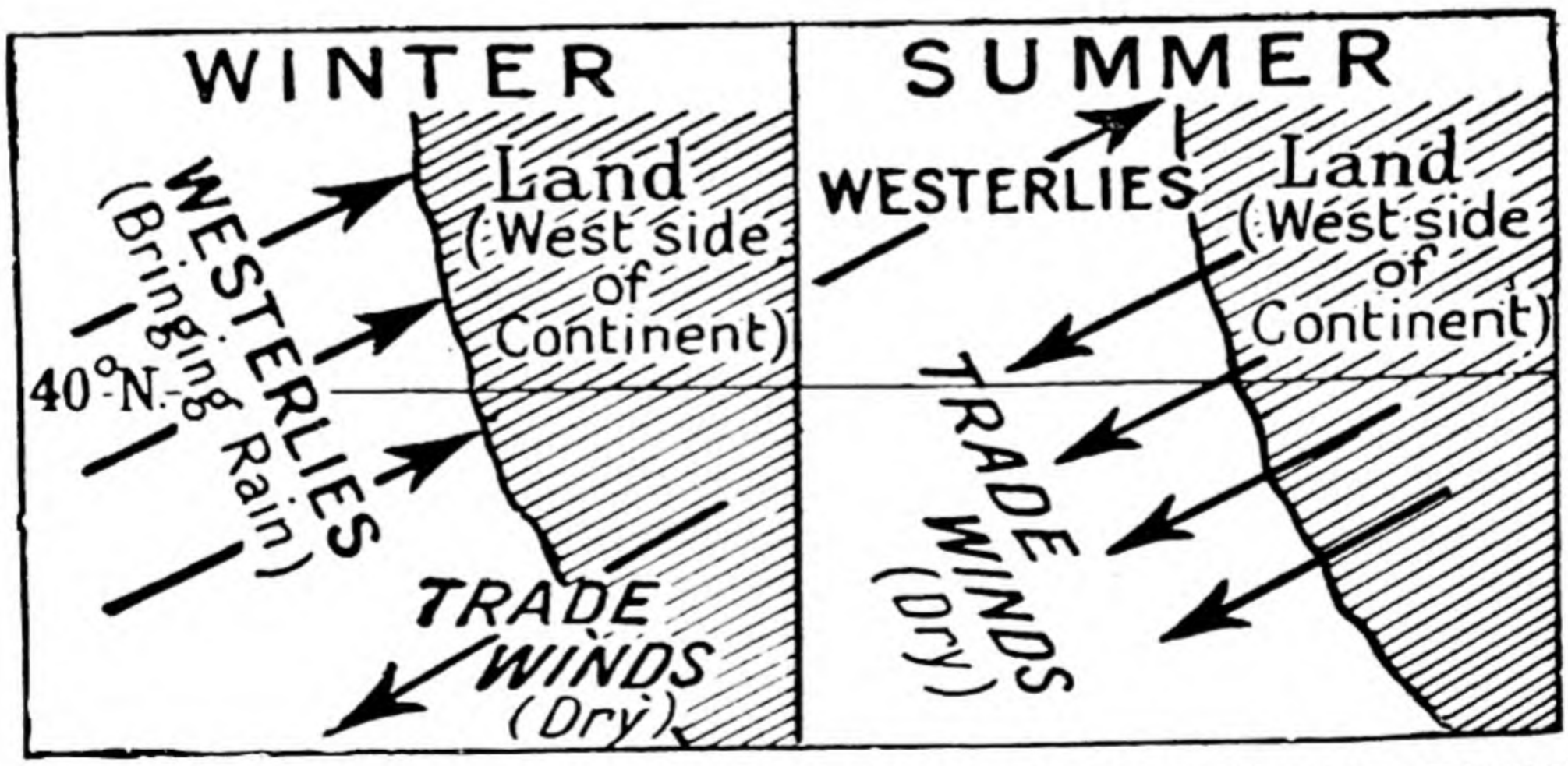


FIG. 68.—A DIAGRAM SHOWING THE CAUSE OF THE MEDITERRANEAN CLIMATE.

regions of the world—some from California, some from other Mediterranean lands. Some of the trees protect themselves from loss of moisture by having a very thick bark. This is of

value as the source of cork. Wheat grows well in some Mediterranean lands. In damper or irrigated regions rice may sometimes be grown (as in Italy).

The climate of Mediterranean lands is so favourable that it has harboured many of the great civilisations of the world—Greece and Rome. But food is easily obtained and the pleasant climate tends to make the people lazy and too easily contented, or to sleep during the heat of the day. In Mediterranean countries the houses usually possess thick walls

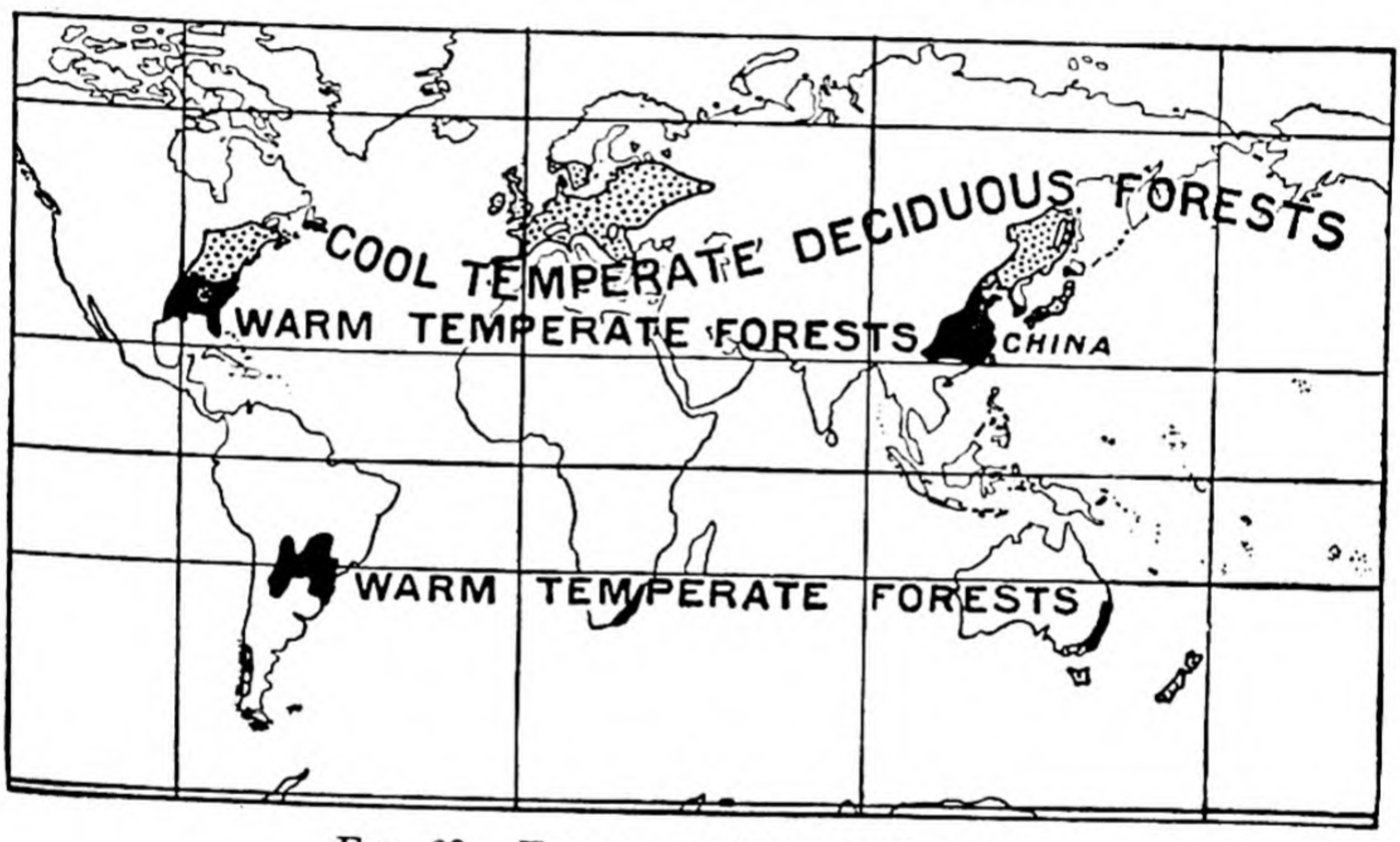


FIG. 69.—TEMPERATE FOREST REGIONS.
Notice that these are found in at least three different climatic regions.

of stone, to keep them cool during the summer, and wide piazzas or verandahs for shade.

(6) *Warm Temperate Forests.*—The lands having a warm temperate climate are forested, and the forests are often very similar to those of monsoon lands but of different trees. Both maize and rice grow well, and these lands are thickly peopled—as, for example, China and the south-eastern part of the United States.

(7) *Cool Temperate Deciduous Forests.*—In the monsoon lands, the trees lose their leaves to protect them against the heat of the hot season. In the cool temperate deciduous forests the leaves are lost during the winter to protect the trees against the cold and frost. In America the end of the

summer is called the 'Fall,' because it is then that the leaves fall from the trees before the cold of winter comes on. Many of the trees of these forests yield valuable wood—oak, elm, beech, birch, and maple. Forests of this kind formerly clothed a great part of North-Western Europe—including England—but have been cut down to make room for agriculture and pastoral industries. Many grains do well in this climate. We must notice that the plants require much less rain than in countries like India, because the sun is less powerful in summer and does not dry up the moisture to the same extent. Eastern England has a rainfall of about 25 inches (roughly the same as the driest parts of the Deccan in India, which are bare and brown half the year), yet the country is clothed with green grass for the whole year. Also we find wheat growing actually better in the drier parts, as in the east of England, than in the wetter parts. In damper regions the grass grows richly and affords fine pasture for cattle. Sheep are found in the drier or hilly parts. On poorer soils and farther north wheat is largely replaced by oats. Barley likes the same climate as wheat, but will grow also in cooler places. Over much of the continent of Europe rye is grown under the same conditions as oats. There is no grain which furnishes such good and nourishing bread as wheat, and the demand for wheat, already enormous, increases yearly amongst the white races. On p. 100 it was noted that the eastern side of North America, around the St. Lawrence and the New England States as well as Manchuria on the east of Asia, had much colder winters. In this, the 'St. Lawrence type' of climate, mixed forests of deciduous and coniferous forests occur. The climates are healthy and invigorating. Hard work during the whole year is needed in farming; it is not too hot in summer to prevent work during the whole day, and in the winter work is essential to keep warm. So we find the great North European and American civilisations have been fostered by these climates. The houses must be substantially built, for the winters can be very cold and there is no season of the year when rain does not fall.

(8) *Temperate Grasslands.*—The grass in temperate continental climates is usually shorter and less luxuriant than in tropical grasslands, and flourishes even with a rainfall of less than 15 inches. There are vast stretches of these lands without a single tree. The temperate grasslands have received different names in different continents—Steppes in Asia and Europe, Prairies in North America, Pampas in South America,

High Veld in South Africa, and Downland in Australia—but they are very similar throughout. In spring the ground is fresh and green and rich with flowers; in summer the sun scorches the grass and the whole country becomes brown; whilst in winter it is often snow-covered, and the rivers turned to ice.

As in the tropical grasslands, we find swift-footed grass-eating animals. The horse, ass, and sheep are all typical of these lands.

The inhabitants of the grasslands are nomads. They wander about from place to place with their flocks, for when the grass dries up in one region, a move has to be made to find fresh pasture elsewhere. In richer regions cattle are most important, in drier parts sheep and goats. The people are fine horsemen, for they have to spend much of their time riding, watching the vast flocks and herds. In past ages the grasslands have acted as great 'reservoirs' of people. After a series of bad seasons it may be necessary for a great mass of people with their herds and flocks to move bodily in search of fresh lands. In this way great waves of people have swarmed out of the grasslands and settled in surrounding countries. In the centre of Arabia are grasslands from which the Arabs have come out and overwhelmed the lands round about.

In recent times the richer areas of grassland have been rendered suitable for wheat cultivation, and farming has largely replaced the pastoral industries.

(9) *Cold Temperate Coniferous Forests.*—Stretching as a great belt across the Northern Hemisphere is a vast tract of evergreen trees with needle-shaped leaves—trees which yield valuable soft timber. Much of the moisture in this region falls as snow and not as rain. The forests are inhabited by animals which have a thick fur to protect them from the bitter cold of winter. So many of the inhabitants are hunters. Naturally logging and timber-working industries are important. The trees are felled during the winter, dragged over the slippery snow and floated down the rivers when the snows melt.

Similar forests cover large areas of the higher regions of Central Europe—there are fine forests on the mountains of Germany and Switzerland and the Carpathians. Wood is abundant and so is the general material for dwellings, which range from the rough log-huts of the North American settlers to the fine wooded 'chalets' of Switzerland. The mountainous parts of New Zealand, Tasmania, and South-Eastern Australia

are sufficiently cold for coniferous forests to grow well. Except in plantations, however, there are no true pine forests in Australasia, and the area of such forests in the whole Southern Hemisphere is very small. In the coniferous forests fire is something very much to be feared, for it destroys the whole forest and is very difficult to check.

(10) *The Tundras or Cold Deserts.*—In Arctic and Antarctic regions are vast stretches of desert land—desert not because of the heat as in the hot deserts, but because of the extreme cold. It is too cold for the growth of trees, and practically the only vegetation is moss and lichens. The reindeer is almost the only animal, and furnishes meat, milk, and clothes for the few poor inhabitants of these dreary 'barren lands.' Agriculture is impossible, for the ground is frozen for three-quarters of the year. In some parts of the tundras the short, sharp summer produces a wealth of flowers, but for the remainder of the year the ground is snow covered.

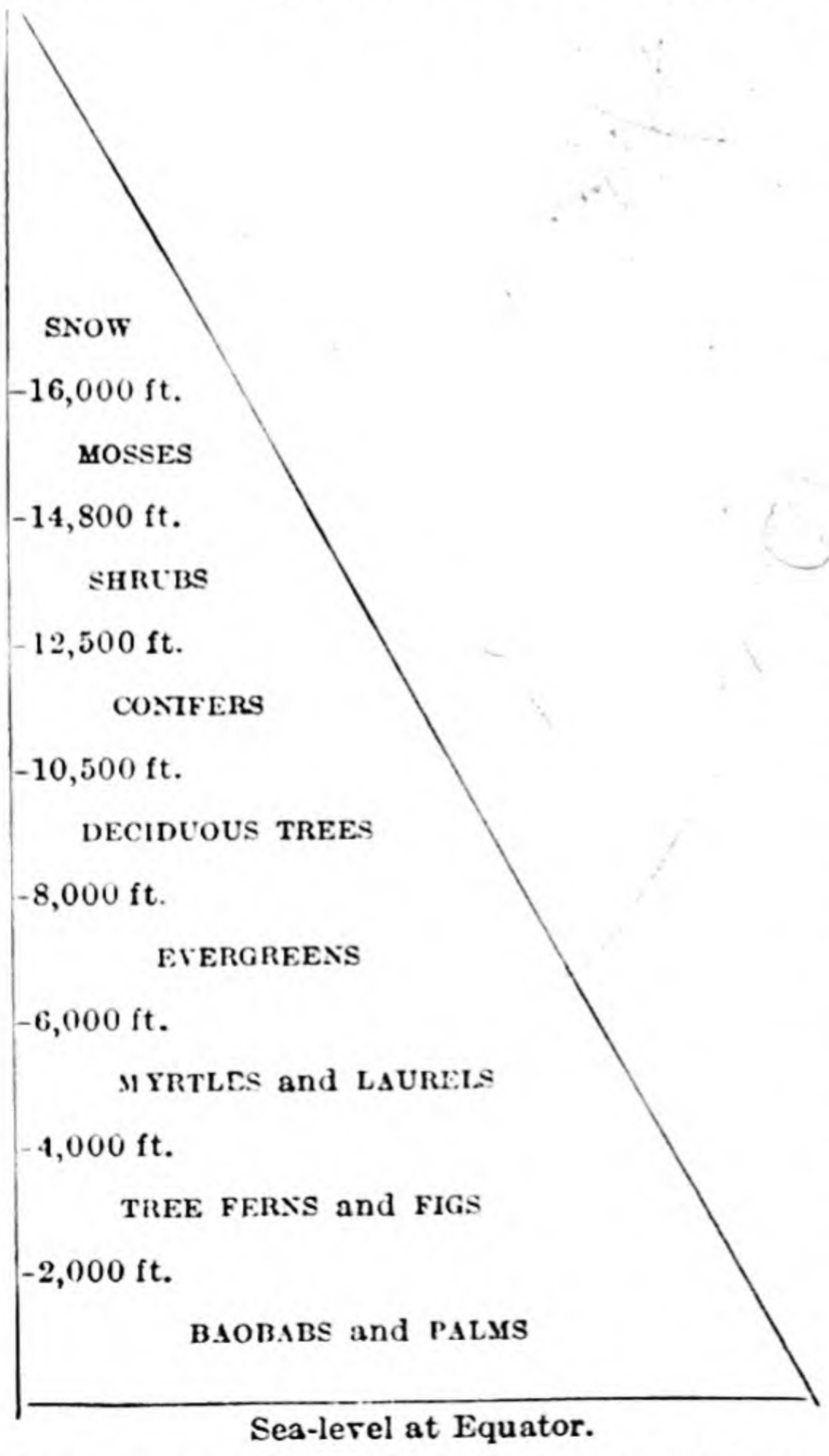


FIG. 70.—VERTICAL ZONES OF VEGETATION.

66. **Vertical Zones of Vegetation.**—In speaking of climate it has been shown that a rise in altitude produces the same effect as regards temperature as increase in latitude. Hence in ascending a high mountain near the equator we shall pass through regions of vegetation similar to the horizontal zones at the sea-level. From a region of palms and bananas near the base we shall pass through the other zones, until at 16,000 feet we leave the zone of lichens and mosses for everlasting snow. (*See* Glossary 'Snow-line.') These vertical zones may be represented as in fig, 70.

These vertical zones have often been referred to by travellers. Speaking of Kilimanjaro, the highest mountain of Africa, situated at latitude 3° S., a recent traveller says : 'The summit clothed with virgin snow, the upper regions bearing the humble plants of temperate climes—the heath, the hounds' tongues, the forget-me-nots, buttercups, clematises, anemones, violets and geraniums, the brackens, polypodies and male fern that are always associated with the flora of our chilly lands ; and then, descending through rich forests of tree-ferns, dracænas, and moss-hung mimosas, to the vegetable wealth of the equatorial zone—to the wild bananas, palms, orchids, india-rubber creepers, aloes and baobabs.' Even in Europe we may begin the ascent of the Alps in the midst of vineyards, but at a height of less than 2,000 feet these disappear, to give place to oaks and beeches.

67. **The Chief Commercial Products of the Vegetable Kingdom.**—Let us now consider some of the most important crops in the world.

Rice.—Rice is the most important food grain in monsoon countries. It is quite different in its requirements from all other grains. The seeds must be sown in a clayey or loamy soil under a few inches of water, and the young plants grow up through the water. As a rule the seeds are sown in 'nurseries,' and then the young plants are taken up and planted out by hand in small tufts—again under water. This is very hard work, but the yield of rice is very good and it pays for the trouble. The roots must be surrounded by water until the plant has reached a good size. Then the fields are allowed gradually to dry and the grain to ripen with the sun's heat. It will be seen that rice requires a great deal of water, and flat land so that the water does not run off. The best land for rice is in the great alluvial plains and deltas like the Ganges Valley and the Irrawaddy Delta. In more hilly countries paddy or rice fields must be made by 'terracing,' so that the fields are like a number of flat steps down the hillside or valley. We see this in Ceylon and in many parts of Burma as well as in various parts of India. To do well rice requires 60 or 80 inches of rainfall ; with less than that the crops may fail. But huge quantities of rice are grown in irrigated areas, such as the Indus Valley and the dry part of Burma, where the water is brought artificially to the land by canals which man has made.

Rice with the husk on is called paddy, and so Indians nearly always talk about 'paddy-growing' and 'paddy-

fields' ; but European peoples, who only see the paddy when the husk has been removed, call it 'rice.'

In monsoon countries the seed is sown during the rains, and gradually ripens as the rains cease, and is ready for cutting in the cold weather or a little later. In countries nearer the equator, where there are two rainy seasons, two crops a year are often possible. We saw that the Warm Temperate Oceanic Climate is very like the Monsoon Climate, and it is also very favourable to rice. Notice in what parts of the world we find (*a*) Monsoon Climate, (*b*) Equatorial Climate, (*c*) Warm Temperate Oceanic Climate. These will be the rice-producing areas, and more rice will be produced where the lands are inhabited by civilised peoples. A little rice can be grown in some parts of the Mediterranean regions where there is sufficient water. The grain grows in the warm moist winter and ripens in the early part of the hot summer. Look at the map and notice the countries.

Maize or Indian Corn.—This grain does not require nearly so much water as rice ; it grows, too, in cooler places. We must notice, too, that it is grown for several purposes ; sometimes the grain is required for food, but at other times it is grown as feed for cattle, both the luscious green shoots and the corn being used. It only rarely forms the principal food of a people, and so it is grown in patches over large areas of the world, but not as the principal crop. Over parts of the United States, however, it is the principal crop. In South Africa it is the principal food of the natives.

Wheat.—Wheat is the most important of all grains since it makes the best flour and bread, that is, the best for the growth of man's body. It forms the principal food of nearly all white peoples, and the demand increases yearly. As a result very large areas are given over to wheat cultivation. There are many different varieties, and a variety which is suitable for growth in India with a monsoon climate will not grow at all in England with a cool temperate climate. All varieties of wheat require :

(*a*) Rain or moisture to make the young plant grow. The growing season should be long, cool, and moist.

(*b*) Sufficient sun to ripen the grain. The ripening season should be warm and dry, but not too hot. The temperature must be at least 60° F. for three months. It is important to have a little rain just before the grain ripens. This rain helps to 'swell' the grains and make them fine and large.

(*c*) A good or moderately good soil : wheat would die if

planted in flat, swampy fields like rice. The best land is gently waving or undulating land, where stagnant water cannot remain round the roots of the plant.

In different countries we find wheat is planted and reaped at different times in order to fit in with the climate :

Cool Temperate 'winter wheat' is planted about November in the Northern Hemisphere and April or May in the Southern. It remains in the ground all the winter—it is better if the ground is covered with snow—grows during the spring, and ripens during the summer, so that it is cut in the early autumn.

Temperate 'spring wheat' is sown in the spring after the winter frosts and snows have gone, but is cut at the same time as the winter wheat.

Tropical Climates (as India).—The seed is sown in the latter part of the rains, and is ready for cutting in the early part of the hot season—January or February in India—but before the great heat commences. It is important that it should have a little moisture about December in order to 'swell the grain.'

You must remember that wheat is a *grass* which has been carefully cultivated by man. Like the natural grasses, it will flourish best in the Grassland Climates of the world. Just find where the temperate Grasslands occur. You will find these are the principal wheatlands of the world. Study the map fig. 65 (p 105). Wheat also grows well in the drier parts of the Cool Temperate Oceanic Climate. The deciduous forests of these lands have been much cleared and wheat grown. North-Western Europe has this climate, but in the wetter parts the wheat will not grow. It also grows in a Mediterranean Climate as in Italy or Spain.

Oats, Barley, and Rye.—These are other important grains of temperate lands. They flourish where wheat flourishes, but will also grow in colder climates and poorer soils, and hence are found farther north in the Northern Hemisphere. Oats like a cooler and damper climate than wheat, barley will grow in a great variety of soils and climates, whilst rye will grow in the poorest soils and in climates too severe for wheat. But they all belong mainly to the temperate zone. Rye is especially important in the North European Plain.

Millets.—Millets of different kinds are important grains in the Tropics, especially in India, where they grow with a very much smaller rainfall than rice. All over the drier parts of Africa they furnish the principal food grain of the native population.

Sugar comes from two entirely different sources—the sugar-

cane of hot, wet countries, and the sugar beet (which is a 'root crop') of temperate climates. The most important producers of cane sugar are the West Indies and Java. Queensland now produces more cane sugar than Australia herself requires, and Natal as much as South Africa needs, but India not enough for home requirements.

Tea is a very favourite drink in many temperate countries and many other parts of the world. Yet the countries which drink most tea cannot produce it themselves. Tea thrives with a monsoon or warm temperate (China type) climate and must be grown on well-drained soil, and hence is usually found on hill slopes. We find the necessary conditions in Ceylon, Assam, the East Indies, Japan, and China.

Coffee also grows on slopes, but requires more heat than tea. It might be grown in many countries, but comes principally from Brazil, other South American countries, and Java.

Cocoa is obtained from the big beans of a tree growing in the Equatorial Climate on low lands—especially in the Gold Coast, South America, the West Indies, and a small island called Sao Thomé off the west coast of Africa. Chocolate is obtained from the same source.

Mediterranean Fruits.—There is a large variety of fruit trees which thrive in the Mediterranean Climate. You have learnt of some of them. The vine, whose fruits (grapes) are made into wine, is the most important. We find wine is produced in four of the five regions of the world where the Mediterranean Climate is found. Why is it not produced in North America? Another, the olive, furnishes olive oil, which is used by the peoples of southern Europe in cooking, just as we use butter.

Cotton is a fibre obtained from the seeds of a plant which grows in the drier parts of monsoon lands, or in the Warm Temperate Oceanic Climate. Thus you find it growing in most of the countries which produce rice, but in the drier parts of them, but most comes from U.S.A.

Flax, from which linen is made, is the fibre of a plant grown in temperate climates. The same plant grows in the tropics, but it is grown there for the sake of its seeds (linseed), from which oil is obtained.

Jute, from which sacks are made, is the fibre of a plant grown in the delta of the Ganges. Very little is grown elsewhere.

Rubber is obtained from the juice of several trees growing in the Equatorial Rain Forests. It is now mainly obtained

from trees which have been planted in countries in or on the borders of the Equatorial Belt such as Ceylon and the Malay Peninsula (Plantation rubber), but some is still obtained from the trees growing wild in the Amazon and Congo Basins.

Opium is the dried juice obtained from the seed vessels of a kind of poppy grown in Turkey, China and Egypt. The *timber* from the various trees mentioned on page 102 has many uses. Most tropical trees are heavy and have a close grain. *Ebony* is a hard black wood obtained from Ceylon and the East Indies; *mahogany* comes from Central America; *teak*, much used in ship-building, grows in Burma and India and contains an oil that prevents insects from burrowing into it. The *coniferous trees*, *pines*, *firs*, *larches*, and *spruce*, flourish in the colder parts of the temperate zone (the Coniferous Forests, p. 111). The wood has a coarse texture and is used for building and rough work. Large quantities of these trees are reduced to pulp, and such *wood-pulp* is now largely used in paper-making, being imported chiefly from Sweden, Norway, and Canada. *Esparto* or *halfa* is a coarse tall grass growing in Spain and North Africa, and is also used for paper-making. The *condiments* or spices are mainly the products of tropical lands.

68. **The Geographical Distribution of Animals.**—The whole assemblage of animals native to a region is termed its **fauna,** and, as in the case of plants, animals are largely dependent on climate. On this account animals have been divided into a tropical, temperate, and an Arctic fauna.

(1) **Tropical Fauna.**—The tropical regions contain a great variety of animals: the chief carnivora or flesh-eaters, lion, tiger, leopard, panther; many large mammals, as the elephant, rhinoceros, hippopotamus, tapir; the crocodile, alligator, turtle, boa, and the larger reptiles; the chief apes and monkeys, with the palms and other tropical plants on which they feed; many birds of brilliant plumage, as the ostrich, flamingo, the humming-birds, parrots, and toucan; termites, or white ants, and many brilliant insects.

(2) **Temperate Fauna.**—In the Temperate Zone, on each side of the hot belt of the earth, we find the chief ruminants (animals that chew their cud), the ox, the bison, buffalo, deer, goats, and sheep; such carnivora as the bear, wolf, fox, lynx; the Bactrian camel, horse, and ass; the eagle, hawk, common fowl, goose, grouse and pheasant, with the chief songsters, among birds. Reptiles and insects are fewer and smaller the farther we leave the tropics.

(3) **Arctic Fauna.**—In the Arctic zone we find the reindeer, the musk-ox, the polar bear, the arctic fox, sable, and other fur-bearing animals. Whales, the walrus or sea-horse, and numerous kinds of seals, inhabit the Arctic seas.

Animals, like plants, have also a certain range of elevation. The lion, the camel, and the elephant range up to 4,000 and 5,000 feet in the countries they inhabit ; but the tiger may be found at a height of 9,000 feet. The llama, the alpaca, and the vicuña dwell on the high slopes of the Andes, and do not flourish near sea-level. A variety of sheep thrives on the elevated plateaux of Tibet, and is used as a beast of burden in traversing the passes of the Himalayas ; while a kind of ox, the yak, is found in Tibet at an elevation of 14,000 feet. The proper **habitat** of the condor is on the ridges or cordilleras of the Andes, 14,000 feet and upwards, whilst its European representatives, the vultures and the eagles, are found on the Alps, at a height of about 9,000 feet.

On looking more closely we soon find that the arrangement of animals into climatic zones leaves many of the facts of animal distribution unaccounted for, as in the case of vegetable distribution, but more so. Districts where the climate and other conditions are the same have quite different fauna. Thus the monkeys of America are different from those of the Old World ; the ostrich and the giraffe occur only in the wilds of Africa ; the kangaroo only in Australia ; the tsetse-fly, whose sting is fatal to cattle, only in certain areas of Africa ; while no elephants are found in America. Yet we find what may be called *representative species* in districts widely apart ; for the lion and the tiger of the Old World are represented by the puma and the jaguar in South America, the camel by the llama and vicuña, the wild ox of Europe by the bison of North America, the true ostrich of Africa by the rhea of the South American pampas and the emu and cassowary of Australia and its neighbourhood. Australia is a most peculiar region, all the forms of mammalia found in other parts of the world being absent, their place being taken by marsupials, or pouched mammals (kangaroos, wallabies, wombats, etc.), with monotremes, or egg-laying mammals (duck-billed platypus and echidna). The carnivora (for the dingo, or wild dog, was probably introduced by man), the insectivora, and the ungulata (hoofed animals), are entirely absent, while the rodents are represented by a few small rats and mice. The present animal life does not represent the indigenous fauna, for the horse, cow, sheep, pig, and prolific rabbit, were introduced by man. In fact Australia, with the neighbouring islands, is quite a distinct zoological region, cut off from Asia by Wallace's line, a deep channel between Bali and Lombok, and on through Macassar Strait. This fact again points to the deep sea as a barrier preventing migration and transport. Other barriers are high mountain chains like the Himalayas, and great deserts like the Sahara. It also indicates, with other facts, the conclusion that the zoological regions, or faunal realms, are regions separated from one another not only by great differences of climate, but by isolating physical barriers. The more complete are the barriers to migration, and the longer they have existed (for geology teaches

Geographical Distribution of Land Animals (Mammalia).

—	EUROPE	ASIA	AFRICA	NORTH AMERICA	SOUTH AMERICA	AUSTRALIA
CARNIVORA (flesh-eating)	Wolf, Dog, Fox, Lynx, Bear, Wild Cat	Lion, Tiger, Leopard, Hyæna, Dog, Fox, Jackal	Lion, Panther, Hyæna, Jackal, Fox	Puma, Bear, Glutton, Racoon	Puma, Jaguar	Dingo (?)
RUMINANTIA (cud-chewing)	Ox, Sheep, Goat, Deer	Ox, Camel,[1] Antelope, Deer, Goat, Yak	Ox, Camel,[1] Antelope, Giraffe	Moose - Deer, Bison, Musk Ox	Llama, Vicuña, Alpaca	—
RODENTIA (gnawing)	Beaver, Rat, Mouse, Squirrel, Hare, Rabbit	Squirrel, Porcupine, Hare, Rabbit, Jerboa	Squirrel, Porcupine, Hare, Jerboa	Beaver, Squirrel, Hare	Porcupine, Chinchilla	Porcupine
EDENTATA (toothless)	—	Manis (or Scaly Ant-eater)	Scaly Ant-eater	Armadillo	Ant - eater, Sloth, Armadillo	Porcupine Ant-eater, Platypus
PACHYDERMATA (thick-skinned)	Horse, Ass, Wild Boar	Elephant,[2] Rhinoceros, Horse, Ass, Tapir	Elephant,[2] Rhinoceros, Hippopotamus, Zebra	—	Peccary, Tapir	—
QUADRUMANA (four-handed)	—	Orang - outang, Gibbon, numerous Monkeys	Gorilla, Chimpanzee, Monkeys, Lemur [3]	—	Howling Monkeys	—
MARSUPIALIA (pouched)	—	—	—	Opossum	Opossum	Kangaroo, Wombat, Phalanger, Opossum

[1] The Arabian camel, or dromedary, has one hump, and is used in Arabia and Egypt; the Bactrian camel, with two humps, belongs to Central Asia. Camels have also been introduced into Australia.

[2] The Indian elephant has a high, concave forehead, small ears, and moderate tusks; the African elephant has a concave forehead, large flapping ears, and large tusks.

[3] Lemurs are small cat-like monkeys ('half-apes') characteristic of Madagascar, but found also in Africa and India.

that the present distribution of land has not always prevailed), the more do the fauna and flora of regions differ. In regard, therefore, to the distribution of animals, six great zoological regions, bounded by defined physical features, and by the above barriers, are now recognised. These, with their geographical equivalents, are :—

Zoological Regions.	*Geographical Equivalents.*
Palæarctic (old northern)	Europe, Africa north of the Sahara, Asia north of the Arabian desert, Solyman Mountains, and Himalayas.
Nearctic (new northern)	North America to North Mexico, with Greenland.
Oriental	Asia south and east of the Himalayas, including Further India, China, and the Malay Archipelago to Wallace's line.
Ethiopian	Africa south of the Sahara, with Madagascar.
Neotropical (new tropical)	South America and the West Indies, with South Mexico.
Australian	Australia, New Zealand, Papua and islands to Wallace's line, Pacific tropical islands.

From what has already been said, and from the preceding table, showing the distribution of the chief **mammals** (animals that suckle their young), the reader will be able to give the chief animals belonging to the six great zoological divisions. On **island fauna** *see* Question and Answer 115.

The whale, seal, and walrus are not fish, but marine or aquatic mammals, breathing by lungs. They chiefly inhabit polar seas. The baleen whales have no teeth, but horny plates hanging down into the mouth from the palate. These furnish 'whalebone.' The toothed whales are represented by the sperm whale, which is found in numbers, or 'schools,' in tropical and sub-tropical seas. Whales are chiefly valuable for the oil from their blubber, seals for their fur, and walruses for their ivory tusks. The **dugong** is also a marine mammal, with a tapering, fish-like body and two fore-flippers, but no hind limbs. It is found, growing to a length of seven or eight feet, in the East Indian Archipelago. Its flesh is good to eat, and it yields also leather and oil. A similar animal, the **manatee,** or sea-cow, is found in the estuaries of rivers entering the Atlantic from Florida to 20° S.

Among **reptiles** are serpents and crocodiles. The huge python of Africa closely resembles in structure and habits the boa constrictor of tropical America. In India there is the poisonous cobra, in North America the venomous rattlesnake. Crocodiles comprise those found in African rivers, the gavial crocodile of India, and the alligators that inhabit the swamps of tropical America; those in South America are often called *Caymans*.

CHAPTER IX

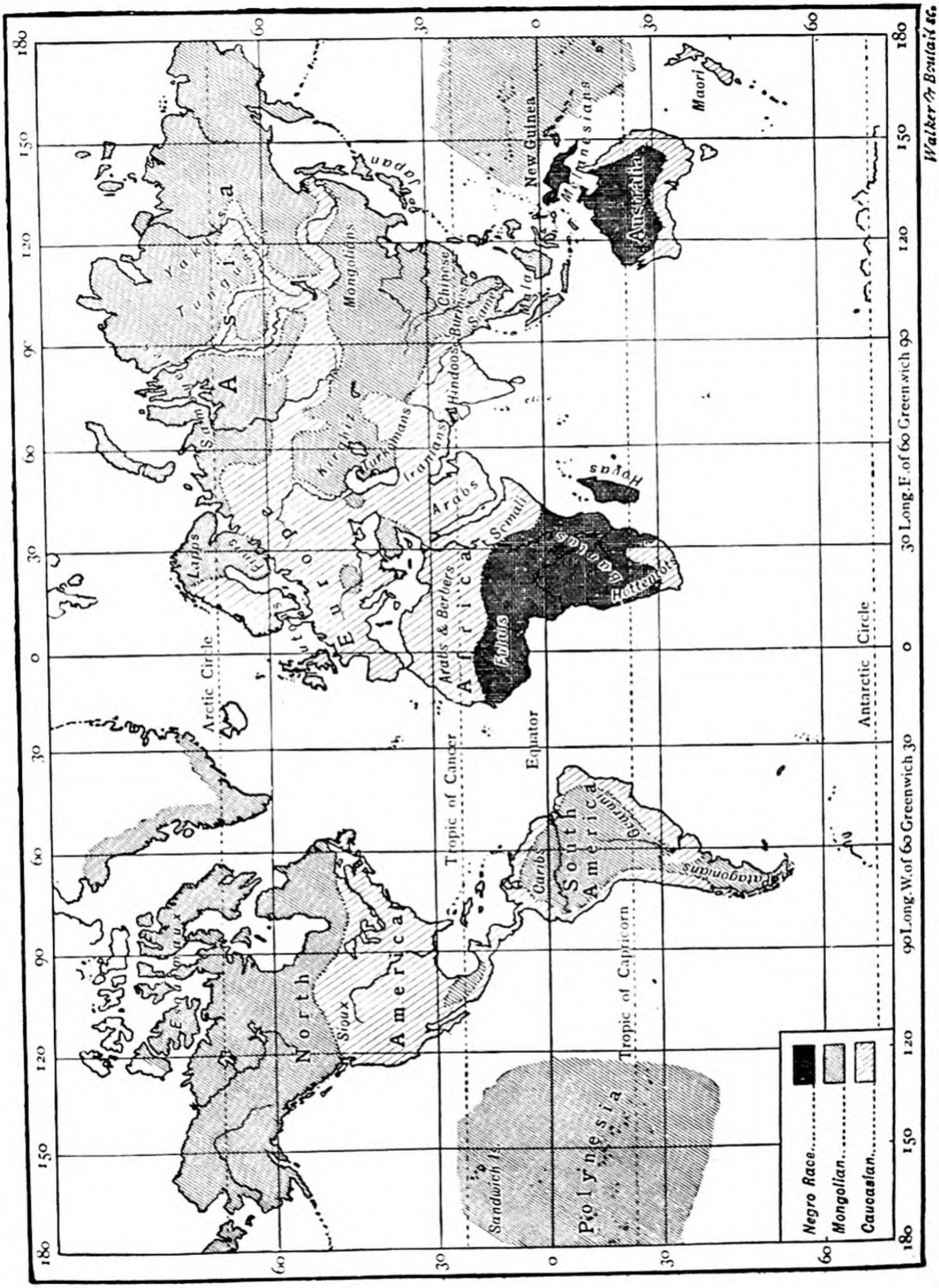
MANKIND. TYPES AND RACES OF MAN. INFLUENCE OF NATURE UPON MAN, AND OF MAN UPON NATURE

69. Man is related to the higher animals in physical structure, but differs from them in spiritual and superior mental attributes. Though there are many superficial differences in physical features, yet it is considered that mankind may be divided into four great groups or types, with certain well-defined characteristics, physical and mental, and that the human family had a common origin in a common geographical centre. Hence man is classified into the four great stocks or types termed **Black or Negro** (or woolly-haired), **Yellow or Mongolic** (or straight-haired) and **White or Caucasian** (or wavy-haired). These types are further subdivided into groups, **races,** and other divisions, a **race** being composed of typical people related by blood. The following table shows, according to Professor Keane, the larger divisions of the three great types, with some of the chief races :—

BLACK		YELLOW		WHITE	
Western	Negro, Bantu	Mongol-Tartar	Kalmuck, Kirghis	Aryan	Teuton, Kelt, Slav, Hindoo
Eastern	Papuan, Australian	Tibeto-Chinese	Tibetan, Japanese	Semitic	Arab, Jew
Negrito	Pygmy, Andaman	Finno-Ugrians	Eskimo, Lapp, Magyar	Hamitic	Berber, Somali
		Malayo-Polynesian	Malay, Maori	Caucasic	Circassian, Georgian
		American-Indian			

The **Black Type, or Negro Stock,** is distinguished by having black woolly or flat hair with little or no beard, a skin dark brown to black, a long and narrow skull, with thick, projecting lips, and a broad, flattened nose. There are two great divisions of the negro stock, the western occupying the continent of Africa from the Sahara southwards, and the eastern, the greater part of Australasia. (*See* Map 8.) The western, or African division, includes the **Negro** proper, of the Soudan region,[1] and the **Bantu,** or South African branch, which includes the **Hottentots,** the **Kaffirs,** the small **Bushmen,** and the **Zulus.**

[1] Many of the negroes of West Africa were carried into the Southern States of America and into the West Indies during the slave trade, and their descendants, now free, still live in these parts.


Negro Race
Mongolian
Caucasian
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle
Sandwich Is.
Polynesia
North America
South America
Caribs
Patagonians
Sioux
Europe
Africa
Lapps
Finns
Arabs & Berbers
Fulais
Hottentots
Somali
Arabs
Iranians
Turkomans
Kirghiz
Hindoos
Chinese
Burmese
Siamese
Malays
Mongolians
Japan
Yakutsk
Tungus
Samoyeds
Hovas
Australia
New Guinea
Melanesians
Maori
Walker & Boutail sc.
90 Long. W. of 60 Greenwich 30
30 Long. E. of 60 Greenwich 90

The eastern division of the negro type includes the **Papuans** of New Guinea, the **Melanesians** of the Solomon, New Caledonia, and Fiji Islands, the native **Tasmanians** (now extinct), and the Australian aborigines, a divergent negro type. A dwarfish kind of negro, termed Negritoes, is found in the Andaman Islands, and as Pygmies in Central African forests.

The **Yellow or Mongolic type** of man is distinguished by having straight dark hair, a yellow to brown skin, a round skull with prominent cheek bones, and a small sometimes narrow

FIG. 71.—NEGRO.

[*Carthew and Kinnaird.*

FIG. 72.—AUSTRALIAN.

nose. The Mongolic stock is very widely distributed, and includes the following branches:—

(*a*) The Mongol-Tartars of North Asia, Central Asia, and Asia Minor, including the nomad Kalmucks of Western Siberia and the Kirghises of Turkestan. (*b*) The Tibeto-Chinese of Tibet, China, Indo-China, and Japan. (*c*) The Finno-Ugrians of Finland, Lapland, the Ural district, and Siberia, with the Esquimaux of North America, and perhaps the hairy Ainos of Yezo, the Kurile Islands, and North Japan. (*d*) The Malayo-Polynesians of the Malay Peninsula (Burmese, Siamese), with the Hovas of Madagascar and the Maoris [1] of New Zealand.

[1] The Maoris, Dyaks of Borneo, Samoans, and other eastern Polynesians, are, however, probably an oceanic division of the Caucasic stock.

The **American Indians,** including all the aborigines of America, with the Esquimaux, in general differ from the other Mongolic type in their taller stature and copper-coloured or reddish skin.[1]

[*Photo : E. N. A.*

FIG. 73.—MONGOLIAN—KIRGHIZ (Turkestan).

The **White or Caucasian type** have mostly wavy hair with full beard, the colour of the skin varies from fair to olive or tawny, the skull is usually long or oval, and they have a straight face. The white or Caucasian type of man inhabits nearly the whole of Europe (the Magyars of Hungary, the Turks proper, Finns and Lapps, belong to the Mongolic stock), India, Persia, and Arabia, and during the last three centuries the Teutonic branch has spread itself over large parts of North and South America, South Africa, Australia, and New Zealand. The white or Caucasian type includes the following branches:—(*a*) The **Aryans or Indo-Europeans,** divided into Hindus, Teutons, Kelts, and Slavs. The

FIG. 74.—MONGOLIAN—CHINESE.

[1] In his *Ethnology* Keane regards the American Indians as forming a fourth distinct group or variety of the human species.

European Aryans are either **fair** as in North Europe, or **dark** as in South Europe. The English and Germans belong to the Teutonic branch, while the Irish, Welsh, and the Highlanders of Scotland are Kelts. (*b*) The **Semitic,** divided into Jews and Arabs. (*c*) The **Hamitic** found in North Africa, and including Berbers in the Barbary States, Egyptians, and Somalis. (*d*) The **Caucasians proper,** *i.e.* the original inhabitants of the Caucasus region. These give their name to the great stock or type, and include Circassians and Georgians.

[*Photo: Carthew & Kinnaird*

FIG. 75.—HINDU (India).

[*Photo: E. C. Stamp*

FIG. 76.—FAIR EUROPEAN (British).

The total population of the world has been estimated at 2,000,000,000. About 45 per cent. of this number belong to the Caucasian type, and 40 per cent. to the Mongolian type. The inborn and peculiar physical and mental qualities of the different races of mankind are largely the result of **environment,** as the sum of surrounding influences and conditions is called, and these, to a certain extent, limit man's habitat. Thus, though the white man can bear great extremes of temperature if the air is dry (Manitoba has a range of 100 degrees), yet the hot damp climate of Western Africa, with a range of only 10 degrees, is detrimental to this race. Europeans find the heat of the tropics so great and exhausting that they cannot sustain manual labour there, and this has to be carried on by negroes or by others native to such climatic regions.

70. **Influence of Climate on Man and on National Character.** Man inhabits all the climatic zones of the earth from the equator to 84° of latitude, yet it appears that a temperate climate, with a regular succession of seasons, is most favourable

to develop ingenuity, forethought, and thrift, and to stimulate that intellectual development that leads to high civilisation. The dense forests of tropical America and Africa are still inhabited by backward peoples, while the very cold regions of the northern hemisphere are the abode of the primitive Eskimo. A hot climate, where clothing is hardly needed, and where the fruit-bearing trees require no cultivation and supply the necessary food, disposes to no exertion, and leaves man undeveloped ; while a severe climate seems only to lead man to secure bare necessities, and then to be content. Temperate regions require the provision of clothing, shelter, and a store of food for the winter season, and these lead to inventiveness, prudence, thrift, and other moral qualities that awaken desire for progress and improvement. Hence it has been said that 'mild climates, soils naturally irrigated, and rich in vegetables, are the natural cradle of agriculture and civilisation,' and that a temperate climate is most favourable to the vigour and intelligence of a nation.

A nation is a political society inhabiting a certain region, within which its government is exercised. It may consist mainly of one race, or it may consist of several. Climate and other external conditions exercise great influence on national character. Thus, the inhabitants of Northern Europe are distinguished by their self-reliance and earnest activity, due to their successful struggle with the hard conditions of their life, but they mature late in life ; while in Southern Europe—the Sunny South—we find the inhabitants at times more listless, though more vivacious, and maturing earlier in life. The moderate climate of the North is, in fact, very favourable to the bodily and mental vigour of the nations there. Again, easy access to the sea, or maritime life, aids greatly in developing national character and the prosperity of a country, for seafaring nations become enterprising, bold, and full of resource, and the easy means of interchange and intercommunication further aids the progress of civilisation. In ancient times civilisation advanced most rapidly in certain countries bordering on the Mediterranean, though, after the clearing of the forests in Britain and North Europe, progress was more rapid among the people in these parts—another illustration of the fact that a variable temperate climate promotes diversity of pursuit, interchange of production, and wealth, leading to progress. On the other hand, great sandy or salt plains, like those of America and Africa, become inhabited by wandering pastoral tribes, who find no motive for improvement.

Climate to a large extent regulates human *occupations*, and these in turn affect character. Inhabitants of mountainous regions are of necessity largely herdsmen and hunters, and this renders them hardy, independent, and disinclined to roam. The dwellers on river plains are tillers of the ground, the men of a sea coast are traders and adventurers, and a ready supply of useful minerals produces miners and manufacturers. Certain climates, too, promote the cultivation of certain plants, while others favour certain manufactures, and thus control or at least influence the industry of a people or district. (*See* Question 186.)

It is important to notice that, as civilisation and man's power over the forces of Nature increase, the physical conditions of the earth affect his employments and habits less and less. Formerly, slight barriers impeded his migrations; now, by the aid of railways, steamers and aeroplanes, mountain chains and great oceans can be readily traversed. Formerly, each country produced its own corn and other food supply; now, these are obtained from the districts that can produce them most cheaply. It follows, then, that though man cannot modify the great climatic conditions of his dwelling-place, yet he is not so much a creature of his environment as in former times.

British emigration and colonisation supply illustrations of the effect of climate on the races of mankind, for the temperate regions of the New World, Australia, South Africa, and New Zealand are now occupied by successful and prosperous communities, while most of tropical Africa and India are rather governed than settled by the white races. The sub-tropical regions of America have been found more suited as settlements to Spaniards, Portuguese, and Italians than to the nations of North Europe.

71. **Influence of Man upon Nature.**—Climate and other natural and geographical conditions have been shown to influence man, but it is also important to notice that man has some influence upon Nature. This latter influence increases as civilisation advances, for the forces of Nature have now been made the servants of man, and thus minister to his needs. Swamps are drained and made habitable, deserts are irrigated and made fertile, rivers have their courses changed, inland towns are united to the sea by canals, suitable sites for cities are prepared, and artificial harbours are constructed. Man also removes forests from hillsides, and thus exposes the soil more freely to weathering influences. In some cases the soil

has, as a result, been washed away, and a barren waste of rock has followed, for a forest covering not only attracts rain, but serves to regulate its passage into the streams.

The vegetation of the world has also been influenced by man. Plants have been brought from one region, and cultivated in another, though in order to do this the climatic conditions must be similar (par. 66). Species of plants have also been modified by cultivation. Further, animal distribution has suffered changes through human agency, for some have been

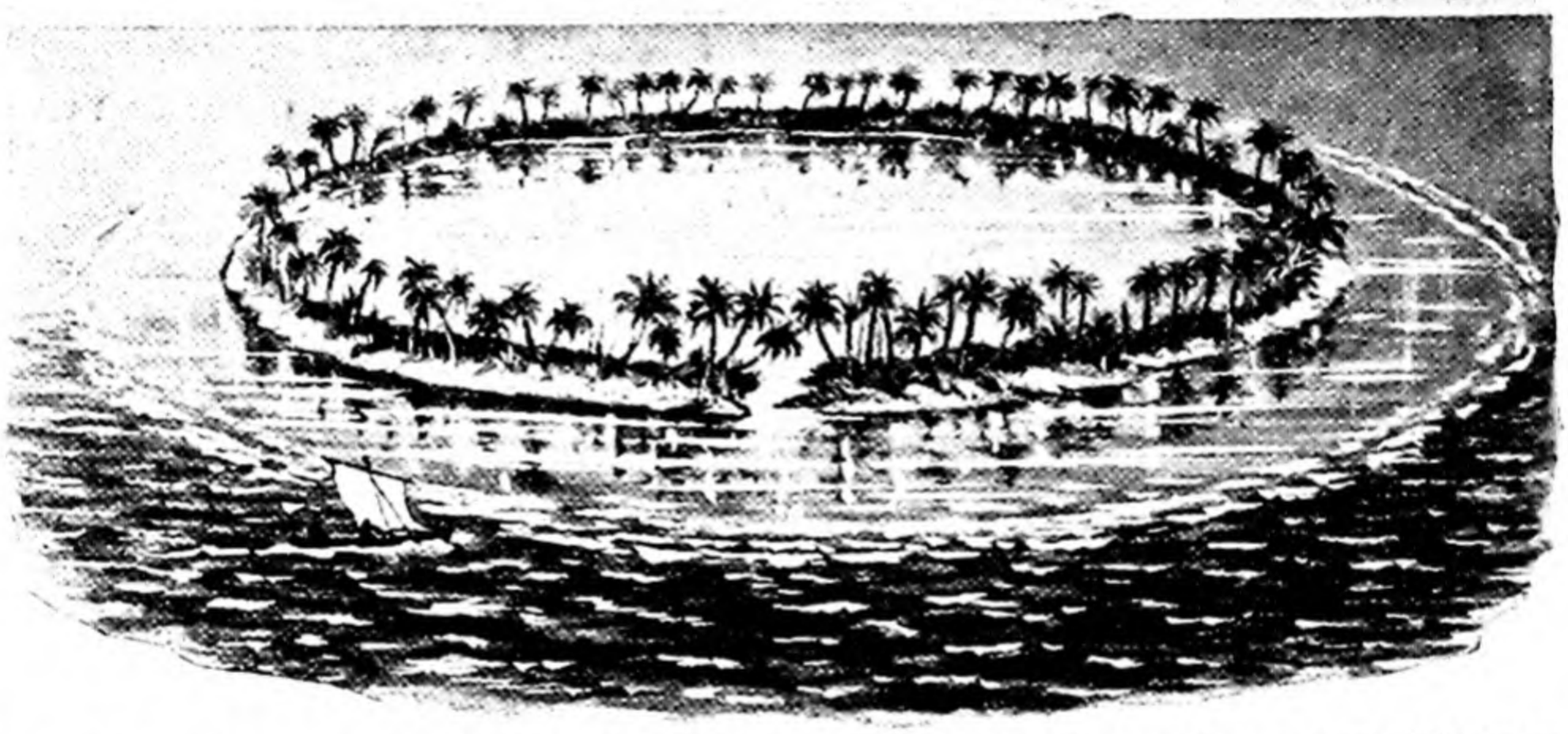


FIG. 77.—AN ATOLL OR PACIFIC CORAL ISLAND WITH COCO-NUT PALMS.

introduced into districts where they did not previously exist. The domestic animals were thus introduced into Australia, and English song-birds into America. Some animals are being exterminated—with advantage in the case of wolves in France and England and deadly snakes in India; with loss in the case of the bison of North America, the elephant and other 'big game' of South Africa.[1]

Man also dispossesses his fellow-man in some districts, and thus affects part of the existing scheme of Nature. Barbarous races appear incapable of adopting a civilised mode of life, and

[1] By the 'big game' of Southern Africa is meant the larger quadrupeds—the lion, elephant, giraffe, hippopotamus, and the numerous kinds of antelopes. It is worthy of note that the tsetse-fly, whose sting is fatal to horses and most cattle, disappears from those districts from which the 'big game' has disappeared.

therefore disappear before races 'superior alike in physical type and in the arts upon which progress depends.' In Tasmania the original black has become extinct, and in Australia his closely related brother seems like to follow in a short time. In North America the 'redskins' are gradually passing away, with hardly any absorption into the present Teutonic inhabitants, though the aboriginal American of the South, having reached a higher civilisation, has been largely amalgamated through intermarriage with the Spanish conquerors, and helps to constitute the mixed peoples of Latin America. A great part of tropical Africa to the north of the Union of South Africa is also undergoing a rapid change of population. The native black races are learning the arts of civilisation in manufacturing, mining and agriculture; while European immigrants are opening up new routes, establishing new industries, and founding new towns and settlements; for at a short distance from the coast the country consists of undulating plateaux from 3,000 to 6,000 feet high, and in the cooler temperature of such highlands white races, even in the tropics, can live and work with comparative ease.

72. **The Sites of Large Towns.**—Consider the causes that lead to the gathering together of large populations in towns and the situation of these towns. In early unsettled times towns grew up around a castle or other fortress on a hill in order that the people might the better protect themselves from attack. Jerusalem, Rome, and Edinburgh are examples of towns founded on hills. As a country became settled the population gathered in the fertile river valleys and on fertile flood-plains and deltas, on account of the abundant food supply and the ease of communication both by land and water. In these positions large towns were gradually formed. Hence we find London, Reading, and Oxford on the Thames; Paris and Rouen on the Seine; Vienna and Belgrade on the Danube; Calcutta, Benares, and several other large towns on the Ganges; Cairo on the Nile, with many other examples. Indeed, most of the densely populated regions of antiquity flourished on the flood-plains and deltas of great rivers, like the Euphrates, the Nile, the Ganges, the Hoang-ho, and the Yangtse-kiang, and such positions still maintain large populations. Large towns have also arisen as seaports near the mouth of a river or by a good harbour, for as the trade of a country grows and communication with other countries increases, a large population is required to handle the exports and imports at convenient places. We therefore find that many of the largest towns of the world are seaports: London, Liverpool, Glasgow, Bristol, Hamburg, Marseilles, New York, New Orleans, San Francisco, and Sydney are examples. The site of some of these towns was fixed in early times at some distance up a river for the sake of security from storms, though they were at that time easily reached by the biggest ships then in use. As modern steamships increased in size the port had to dwindle, or, as in the case of Glasgow, Bristol, etc., the river was dredged and deepened to admit the large vessels.

After the invention of steam-power and various forms of machines large towns soon arose on and near the coal-fields, for the less there is paid for carriage of the coal needed the more prosperous is an industry likely to be. The cotton manufacture settled itself in large towns on the coal-fields of South Lancashire, the soft water of this part being specially suitable for cleaning and dyeing, while the increased manufacture of woollen goods produced large towns in the West Riding of Yorkshire. Coal and iron-ore in the same neighbourhood have given rise to large towns engaged in the various forms of iron manufacture, *e.g.*, Birmingham in Warwickshire, Pittsburg in Pennsylvania, Lille in France, etc.

Some large populations have come together almost entirely owing to valuable mines, *e.g.*, Kimberley and Johannesburg. Gold will always bring together a population, even to such a cold and dreary place as Klondyke.

A few large towns have sprung up as health resorts and holiday places—Brighton, Blackpool, Cannes, Nice, and Ostend are examples. Lastly, there are a few large towns for which special reasons may be assigned. The rapid growth of Chicago from a mere village in 1835 to a town of 3,400,000 at present is due to its proximity to huge grain areas and stock fields, and to its situation at the junction of a network of roads and railways on the side of a great lake ; Essen in the Rhine Province of Germany owes its rapid rise to a town of 650,000 inhabitants because its coal supply led to its being chosen for the seat of Krupp's famous steel works ; Berlin, in a sandy plain on the Spree, has remained the capital of Germany for political and military reasons.

Various causes, mostly conditions favourable to man's prosperity in material wealth, have thus led to the aggregation of dense populations in large towns, and in all industrial countries the steady flow of people to the towns from the country has been noticed. In England nearly one-third of the population lives in the nine largest towns ; more than three-quarters of the population live in towns as distinct from villages and the countryside. This implies the decline of agriculture and the need for importing the greater portion of our food-supply from countries where agriculture can be carried on under favourable conditions.

CHAPTER X

MAPS AND MAP-READING

73. **Maps.**—A map is a representation on a plane surface of a part or the whole of the earth's surface as it would appear from a great height ; that is, it is a reduced facsimile of the part represented, and it is drawn to scale.

In a picture the objects in the foreground appear large when compared with more distant objects, as the scale gets less with the distance from the view-point, while on a map of a small

area everything is shown in its true proportion and at its proper relative distance from other objects, while by means of lines of latitude and longitude the position of the objects is shown in relation to other points on the earth's surface. The *scale* of a map is the proportion between the size of the map and the size of the ground represented, and has nothing to do with the actual size of the map. A small scale means that the map is small in proportion to the horizontal size of the country it represents; a large scale means that the map is comparatively large considering the size of the ground it represents. Large school-room maps and the maps in most atlases are drawn on a small scale, some of them being 1,000,000 or more times less than the natural size. On these maps the reduction is so great that only large indentations of the coast can be shown; large mountains appear as pimples, rivers are shown as black lines, towns appear as black dots, while small streams, villages, and roads cannot be indicated at all. But maps are also drawn on a large scale, one inch to one mile instead of one inch to fifty or more miles, as on wall maps. Such a map will represent a much smaller area on the same space than a small-scale map, but on it by the adoption of a system of symbols or conventional signs much more detail can be given. Roads, railways, small streams, woods, and the general form of a town can be indicated. When one has learnt to *read* such a map—that is, to interpret the various symbols *used*, it conveys a large amount of information. On a still larger scale, six inches to a mile, still more detail, as the shape of fields and the streets of a town, can be shown. The symbols used on the 'one-inch' maps issued by the Government department, called the Ordnance Survey, are shown in fig. 82, and will be referred to again.

The vertical relief of the ground—that is, its elevations and depressions—is exhibited in a variety of ways on a map. On a coloured Map of the World the larger differences of elevation are usually shown by means of various tints, the darkest shade being used for the highest land. The reader should carefully examine a map and note the position of the great highlands of the world, the great plains (below 1,000 feet), etc. Useful and cheap maps of separate countries showing relief by colours are *The Diagram Hand-Maps*, published by Philip & Son. Where colouring cannot be employed differences of height are often indicated by differences of shading. For the sea various shades of blue are often used to indicate the position of the deeper and shallower parts of the Atlantic and Pacific Oceans. The deepest sounding yet made is one of 5,902 fathoms (one and a half statute miles) in lat. 8° N. and long. 128° E. (Par. 33). A common mode of indicating the height of the land is by *contour lines*, as will shortly be explained. The relief of the land

is also shown at times by specially prepared *relief-maps*, *i.e.*, maps in which the form of the surface is shown by elevations and depressions of the material used. Such models of a district necessarily exaggerate the vertical elevations greatly. A photograph of such a model under an oblique illumination gives a *photo-relief map*. We have also maps specially prepared to show only the physical features of a country, so that they are called *Physical Maps*. *Political Maps* are intended to show more particularly the boundaries and extent of different countries and provinces, the towns, railways, etc., though they also indicate many natural features. A map showing a small area of a country in great detail is sometimes spoken of as a *Topographical Map*. If the area mapped is very small much detail can be shown to scale, and the map is called a *plan*. Maps are also made to indicate, by means of colour or different kinds of shading, the distribution of rainfall, the areas producing certain plants, the position of coal-fields, or any other facts that have a geographical arrangement. *Statistical Maps* are also drawn to show such matters as the density of population in certain areas, the districts carrying on certain manufactures, and other results of human industry. We have also maps to show the position and direction of winds, ocean currents, isobars, and isotherms.

Charts are maps made for the use of navigators, and represent especially coasts and harbours with the adjoining sea. Numerous figures on the sea represent the depth in fathoms, and the nature of the bottom, whether mud, sand, or rock, is also indicated. Buoys, beacons, reefs, lighthouses, etc., are also marked. Great Britain has been very active in surveying the sea, and the charts issued by our Government are known as Admiralty Charts.

74. **Contours** and **Hachures.**—The term contour may be defined in several ways, thus :—A contour is a line on a sketch or map which is drawn round a slope or hill at the same level all the way round ; or a contour is the line of intersection of a hill by a horizontal plane ; or a contour is a line passing through all places which are at the same height above *sea-level* ;[1] or contours are the lines to which successive floods of increasing height would rise. A contour line also shows the *shape* of the land at the height at which it is drawn. The vertical distance that contour lines are apart is called the *vertical interval*, and is usually expressed in feet. It may be 20 feet or 100 feet, or larger amounts. Usually the vertical interval is kept the same, but care must be taken where it varies. A map coloured to show elevation may also be regarded as a contoured map, the limits of the various tints being the contour lines. Contour lines are usually drawn as thin black lines, or as in fig. 82. To illustrate the meaning of contour we may take a solid cone of metal or weighted wood and place it in a large vessel, the sides of which are marked in vertical intervals of inches. This cone may represent a conical hill. Its base is circular and may be regarded as the datum line or contour line of no elevation. Now pour water into the vessel to the depth of an inch and mark the position on the cone. This will be a circle parallel to the circle round the base and may be regarded as the contour line of one inch high. Pour in water to the vertical height

---

[1] The height of the sea varies with the state of the tide, but there is an average height that can be found between all the highest tides and the lowest tides of the year, which is called 'mean sea-level.' Sea-level is always taken to stand for mean sea-level. (*See* Glossary, p. 207.)

of another inch and we get the next contour. Continue pouring until the top is reached. We thus get a series of circles which, when projected on a horizontal plane, appear concentric as represented in fig. 78. From these contour lines we can construct a profile or section of the cone, say from left to right through the middle of the base—a section of the line AB. To do this take a base line, either above or below the contours of the same length as AB. Rule parallel to the base line other lines at equal intervals to represent the vertical distances between the contour lines and number them similarly. Now place the paper below the contour map with its horizontal lines parallel to the line of section AB and keep it fixed in this position. From the points of intersection of the section AB with the contour lines, drop, by the aid of a set-square, perpendiculars to meet the horizontal lines. Mark the points where each perpendicular meets its corresponding horizontal line. On joining the

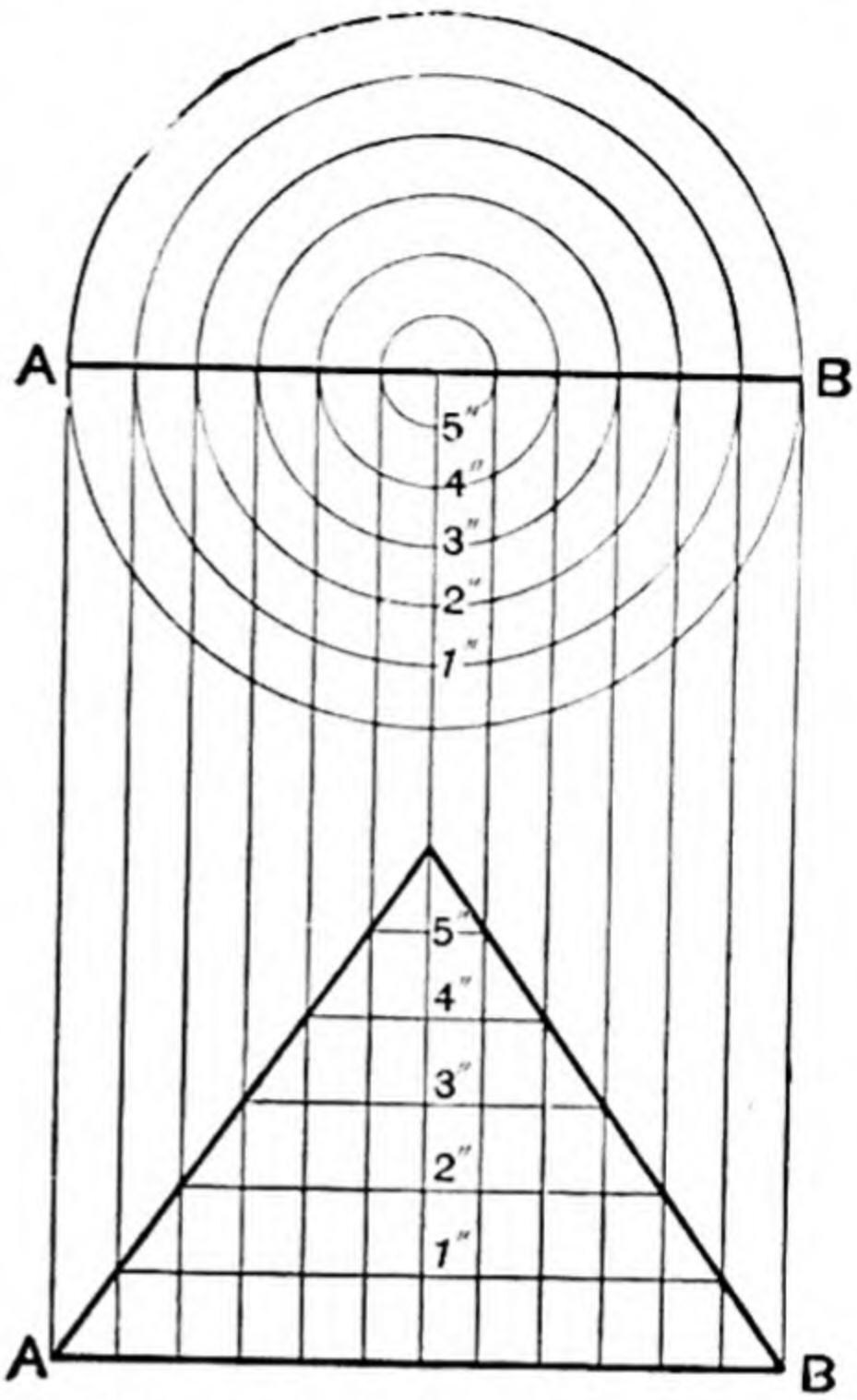


FIG. 78.—CONTOUR LINES ROUND A CONE AND SECTION BELOW ON AB.

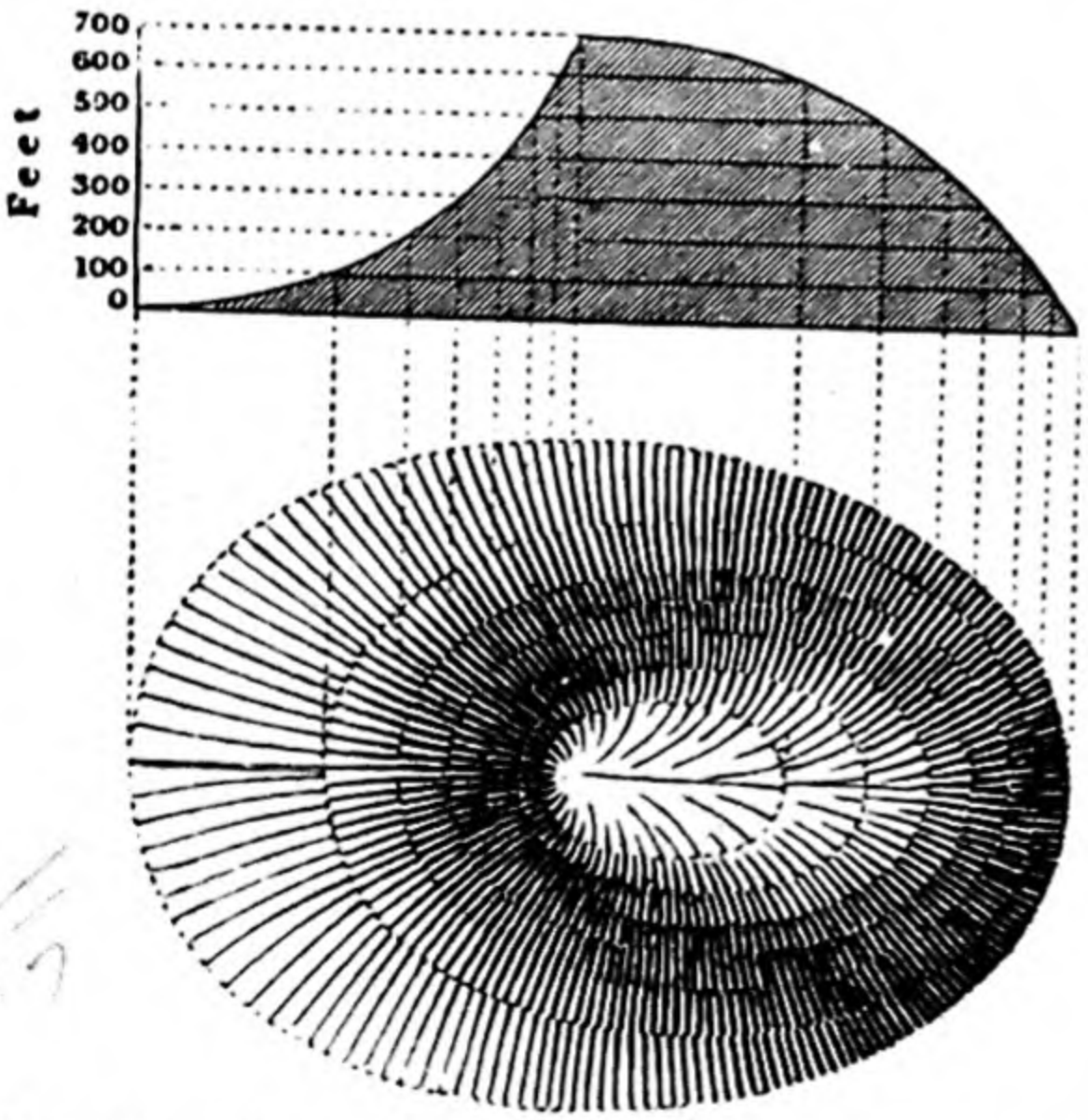


FIG. 79.—CONTOURED AND HACHURED HILL WITH SECTION ABOVE THROUGH ITS LONGEST PART.

points marked, the required section is obtained in outline; such sections are sometimes shaded as in fig. 79. (The horizontal lines on squared paper may also be used in making sections of a contoured piece of land.)

In the case of the cone the contour lines round it form concentric circles at equal distances, since the slope is uniform.

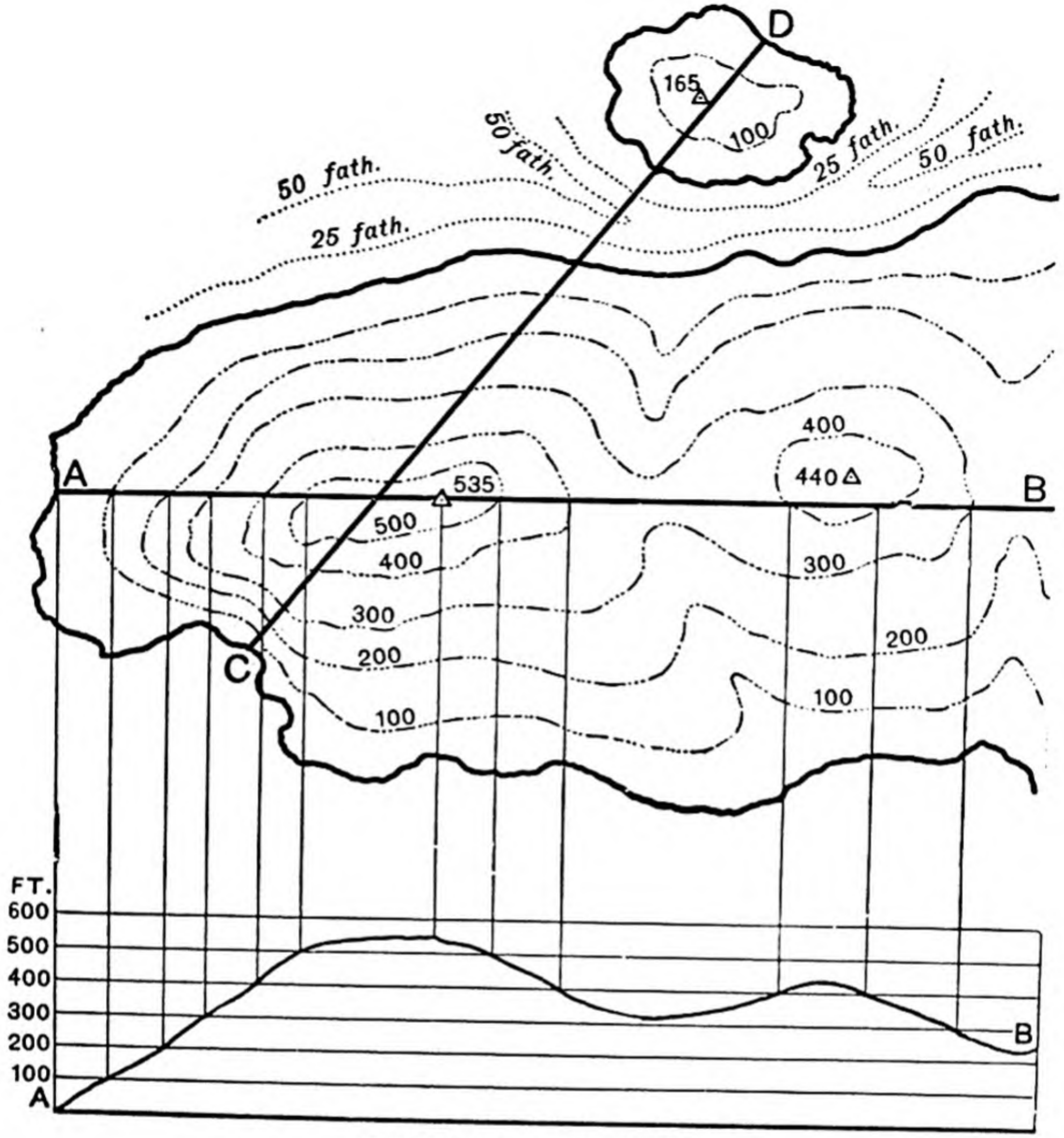
Fig. 79 shows us the contour lines round a hill of somewhat irregular shape, but the highest point of the hill is much nearer one end than the other. We see that in this case the contour lines on the

steeper slope are much closer than where the slope is gentle. A section of the hill is shown beneath.

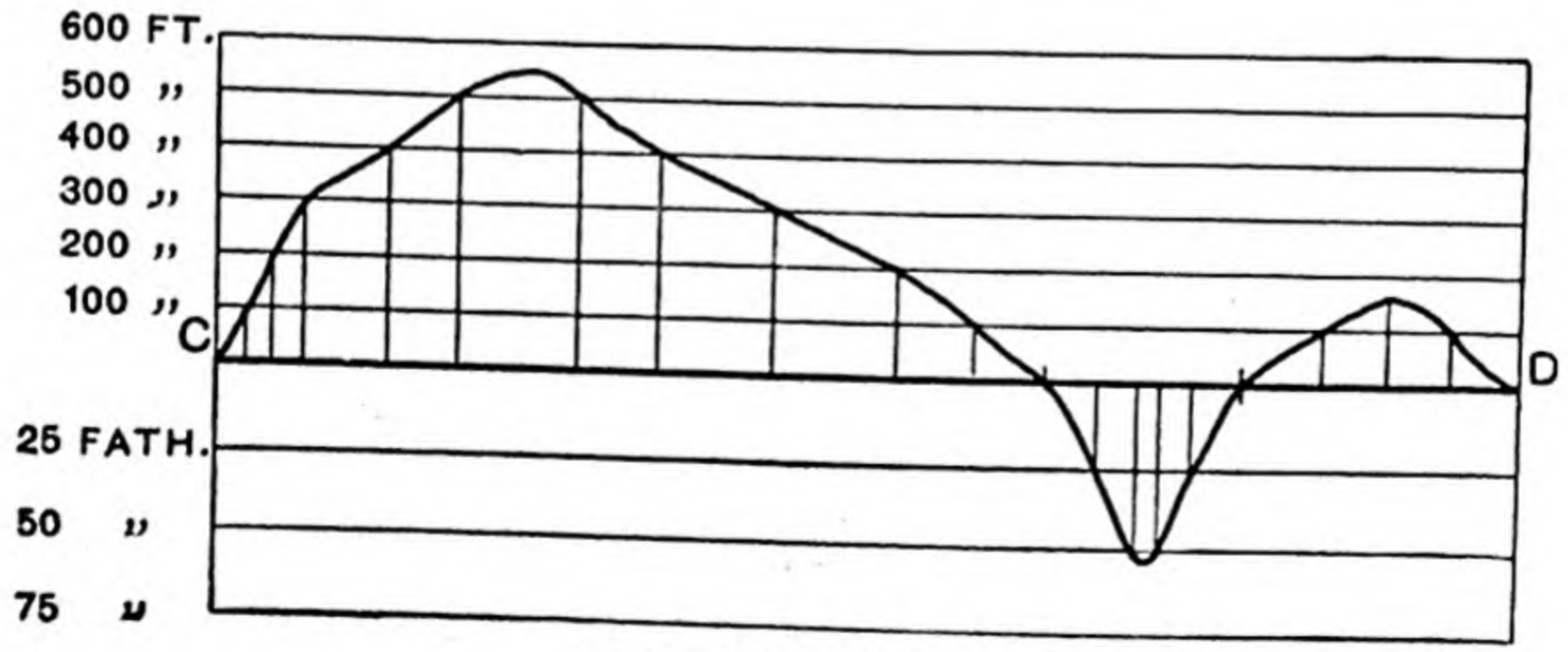
Fig. 79 also shows well the crowding of the contour lines on a steep slope and their spreading out where the slope is small. The contours also enable us to see when a hill has a convex side and a concave side.

Figs. 49 and 79 also show besides the contour lines certain shadings between the contour lines called *hachures* or *hatchings*. Hachures are shading lines drawn directly down the slopes of hills, and they are made thicker and closer the steeper the ground is, so that the steeper a slope is, the darker is the map in that place. With a gentle slope the hachures are thin and far apart. Flat land has no hachures whatever be its height. Hence, where the ground is about level, whether in a valley, on a mountain slope, or on a mountain top, the map is left free of hachure lines and appears white (see Map 9). Hills and elevations in nature, however, have not the regularity of form of solid geometrical models or of those illustrated in figs. 78, 79. The slopes vary at different places so that contour lines usually wander in and out in various ways according to the shape at the height at which the contour is drawn. Let us now consider a more diversified piece of ground such as is represented by the contour lines on fig. 80. Here we have represented a promontory with a small island on the north side. An examination of the contour lines shows us that there are two hills on the piece of land represented separated by a neck or col. The 100 and 200 feet contours are not shown completed, for they close in on land to the east not represented. The highest point on the land, marked by a small triangle, is 535 feet. The island on the north is separated by a deep channel, the depths of this channel being expressed in fathoms. A little effort should enable the reader to picture to himself the shape of the ground at any place from these contours. At which end is the hill the higher ? Where is the slope of the hill steepest ? At which part will it be easiest to pass from the south to the north side of the promontory ? Down which valleys will streams flow ?

Sections are shown across the island in two directions and represented below. The upper one is obtained by the method already explained. The lower section is obtained in another useful way. A piece of paper is taken on which parallel lines at equal vertical intervals of $\frac{1}{8}$ inch are drawn above the datum line. Below the datum line there is a change of contour interval in the sea, from 100 feet to 25 fathoms or 150 feet, so that the distance between the parallel lines which is $\frac{1}{8}$ inch above the datum line becomes $\frac{3}{16}$ inch below. The sea-level is the datum or 0 contour line, and the others are marked with the contour intervals shown. Divide the datum line into lengths equal to those where the section line cuts the contours, in any way, *e.g.*, lay the edge of another piece of paper exactly along the line on which the section is required and with a pencil tick every part where it cuts a contour line, adding to each tick the height of the contour. Transfer these marks and numbers to the datum line and we obtain the datum line divided into lengths equal to those where CD cuts the contours, At each point thus marked on the datum line erect a perpendicular to meet the corresponding parallel section line. On joining the upper ends of the perpendiculars so drawn, the section is obtained. Any number of sections of a contoured map may be thus obtained in order to show aspects of the land from different sides. Draw another from north to south across the hill at the east end, using the method last shown.



SECTION ON A. B.



SECTION ON C. D.

FIG. 80.—CONTOURED PROMONTORY AND ISLAND, WITH TWO SECTIONS THROUGH THE SAME.

It must be remembered that sections are usually drawn on a greater vertical scale than the horizontal scale for the sake of clearness. In fig. 80 the horizontal scale is 2 miles to 1 inch. The vertical scale is 100 feet to $\frac{1}{8}$ inch—*i.e.* 800 feet to 1 inch. As 2 miles = 5,280 × 2 = 10,560 feet, the vertical scale is a little more than thirteen times larger than the horizontal scale. By using the parallel lines on paper with $\frac{1}{10}$-inch squares and regarding the mile as 5,000 feet instead of 5,280, sections with a vertical scale ten times that of the horizontal scale can be quickly obtained.

Contour lines may also be used to show the depth of the ocean. On a coloured map the lines where the different shades of blue meet are the contour lines for ocean depths. From a contoured map of a sea such sections as are shown in figs. 37 and 38 are obtained. Draw a similar section to show the depth of the Atlantic Ocean between the mouth of the Niger and the mouth of the Amazon.

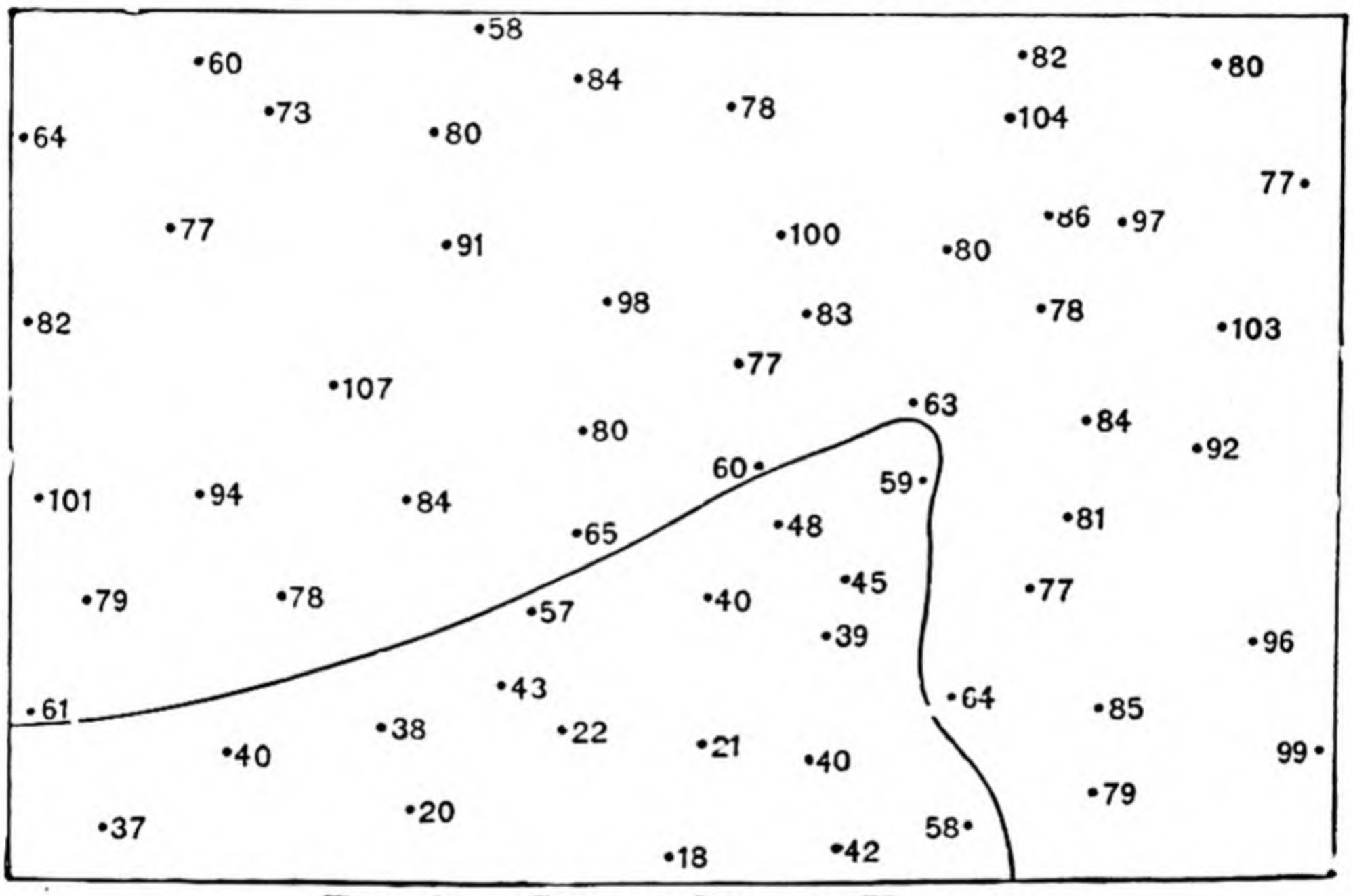


FIG. 81.—SET OF SURVEY HEIGHTS.

If the height of a sufficient number of points be determined by a survey of a piece of ground and put in proper relative position on a piece of paper, we can then draw the contour lines at certain vertical intervals. Fig. 81 shows a number of points with the heights in feet placed after them. From the given heights the reader can draw the probable course of the contour lines at vertical intervals of 20 feet, for where the height is not given in 20 feet or a multiple of 20, we can judge where such a height will be. The contour line for 60 feet is drawn as an example. After putting in the contour lines indicate a stream flowing down the valley line. Also draw a section from the south-west corner to the middle of the east side.

75. **Ordnance Survey Maps.**—The Ordnance Survey Office issues a series of maps on various scales. For school pupils the most useful scales are: $\frac{1}{63360}$ or 1 inch to 1 mile, and

$\frac{1}{10560}$ or 6 inches to 1 mile. There are other scales, some smaller, others larger than the above.[1] To make use of these maps one of the first things to do is to learn to understand the symbols or conventional signs that are used. The most important are shown in fig. 82. Careful attention must be given to these symbols, for, as will be seen, not only are roads represented, but the kind of road is indicated. Not only is a railway shown, but we can see when it runs on an embankment, in a cutting, or in a tunnel. The fine contour lines need careful tracing, for on some very uneven ground they wander about in a complicated way. On plains they are few and wide apart, and sometimes disappear in woods or parks to reappear on

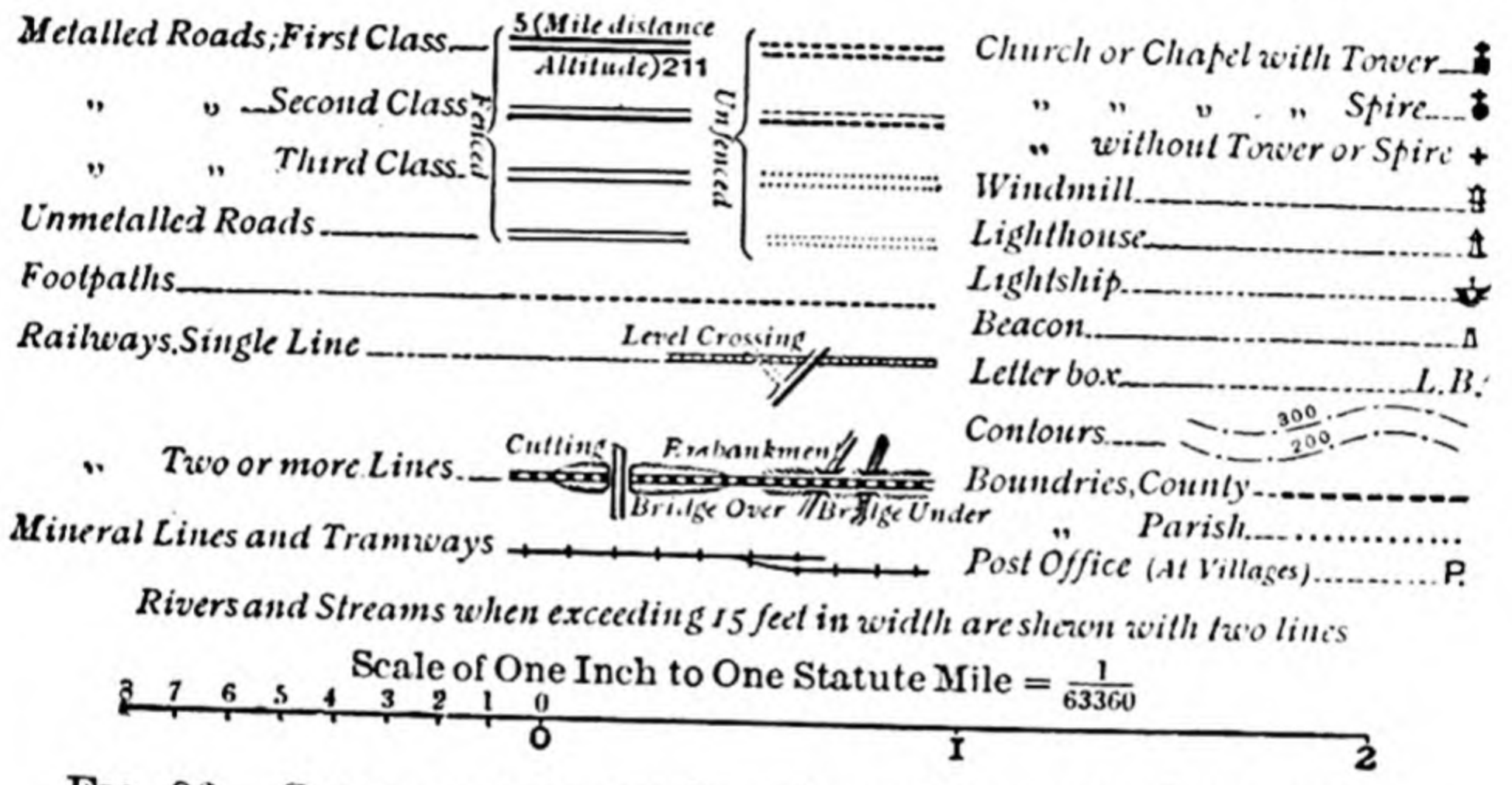


FIG. 82.—SYMBOLS USED ON ONE-INCH ORDNANCE SURVEY MAP (EARLIER EDITIONS).

(The letter T at villages indicates Post Office and Telegraph Office.)

the other side. The numbers printed at intervals along a contour line indicate the number of feet above sea-level. The points of the compass are not indicated, as it is understood that the top of the map is north, the bottom the south, the right-hand the east, and the left-hand the west. Plans of an estate or a large building have usually an arrow to indicate the points of the compass.

As an introduction to the use of the One-Inch Ordnance Map with its many details, we will consider the map marked fig. 83, which has

[1] See the two pamphlets, one on large-scale maps (six-inch etc.); the other on small-scale maps (one-inch, etc.). Price 6*d*. each. These contain, besides explanations, specimens of the various maps, and provide very useful practice in map-reading. From the Ordnance Survey, Southampton.

been designed to indicate a simple piece of ground on which only a few of the chief symbols are used. It represents a contoured piece of ground near the sea-coast on a scale of 2 inches to 1 mile, or expressed in a representative fraction, on a scale of $\frac{1}{31680}$. The lowest ground is where the river runs into the sea ; the highest the top of the hill 135 feet high. The vertical interval between the contours is 20 feet. We see a village near the south shore of a small river. The village has a post office with telegraph (T indicates this), and it has, besides other buildings, two churches. *Of what kind?* From the village a first-class turnpike road crosses the river, and then runs to the north-west with

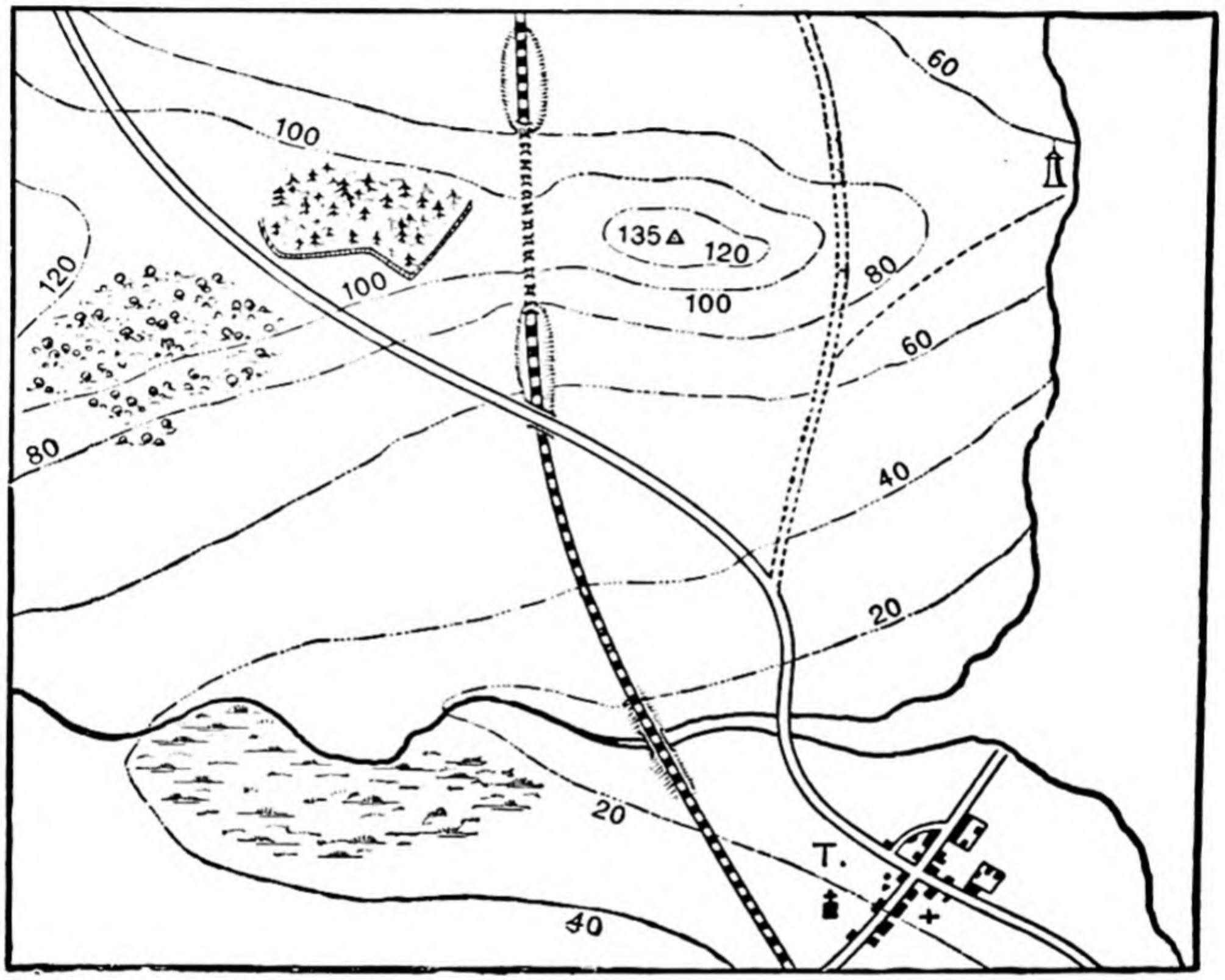


FIG. 83.—MAP SHOWING USE OF SOME ORDNANCE SURVEY SYMBOLS.

a wood on each side. The wood on the north-east consists of firs (coniferous trees), that on the west side of trees that shed their leaves in winter (deciduous trees). Note the symbol for each kind of tree. The main road gives off a branch that is unfenced and runs northward. A footpath leads off from this to a lighthouse on the cliff. A piece of marshy ground lies on the south side of the river, the proper symbol indicating this. From the borders of the village a double-line railway passes over the river to the north. In the low land near the river it runs on an embankment, passes beneath the main road into a cutting, then into a tunnel from which it emerges into another cutting.

After a study of fig. 83 the student may design an imaginary piece of ground himself. Try also the following exercise :—

Draw a sketch showing a piece of ground rising to a hill of 625 feet

on the west. On the sketch indicate, using Ordnance Survey symbols, a main road running near the east side and passing through a wood. Show an unfenced road leading from the main road into another wood on one side. A railway crosses over the main road near the middle to a village on the eastern edge that has a church with a spire. The top of the hill is covered with firs.

76. **The One-Inch Ordnance Survey Map.**—We may now proceed to study the reproduction of a piece of the Ordnance One-Inch Map, with contours and hachures, that includes a portion of the country a few miles west by north of Lancaster. Several editions of the One-Inch Map have been issued by the Ordnance Survey. Starting with the most modern the important ones are :—

(1) The Fifth or Relief Edition, now being issued gradually and of which the first sheet appeared after 1930. On these maps relief is shown by contours, hachures and hill-shading.

(2) The Popular Edition, on which relief is shown by contours only, printed in orange at intervals of 50 feet.

(3) The Fully Coloured Edition, now out of print, which had the contours in red at every 100 feet up to 1,000 feet and after that at intervals of 250 feet and which also showed relief by hachures in brown.

(4) The earlier editions, in black only.

It is absolutely essential that the student should study the actual maps, which may be obtained at special rates for educational purposes direct from the Ordnance Survey, Southampton.

In addition to the ordinary series there are two other series of One-Inch Maps of the greatest importance :—

(1) The One-Inch Geological Maps (New Series), now in course of publication.

(2) The One-Inch Land Utilisation Maps, also in course of publication. These maps have all the details of the One-Inch Popular Edition Maps, including contours, and show in addition the use of the land by means of boldly contrasted colours. They are the most useful maps for the geography student and are obtainable from the offices of the Land Utilisation Survey, London School of Economics, W.C. 2, price 4*s.* each (25 per cent. discount for educational purposes). A piece of one of these maps forms the coloured frontispiece to this volume.

The map here reproduced as Map 9 is one of the Old Series in black only, but it shows in general the type of symbols used. The map (Map 9) is 5·4 inches long and 3·5 inches broad, and therefore represents an area of $5 \cdot 4 \times 3 \cdot 5 = 18 \cdot 9$ square miles. Test your knowledge of the symbols shown by finding as many as possible on the map. Which of the villages shown have churches ? What kind of churches ? Find post offices with and without telegraph office. At Gressingham there is only a letter box, LB. Find different kinds of roads. The main road starting on the west, just south of the railway, comes from Lancaster. Near it the figures 7, 8, 9, 10 and 11 (at Melling) indicate the distance in miles from Lancaster. The figures 66, 85, 164, 129 on the same road indicate heights above the mean sea-level at Liverpool. How many bridges cross the railway ? Do they go under or over ? Now pay attention to the relief of the ground. It is indicated by separate numbers at various parts, by numbers along the contour lines, and by hachures. The parts without hachures are flat, mostly in river valleys, but small flat portions are found on two hills. The lowest ground is where the river Lune runs off the map. The lowest ground definitely figured is 66 feet on the south of the Lune valley, near

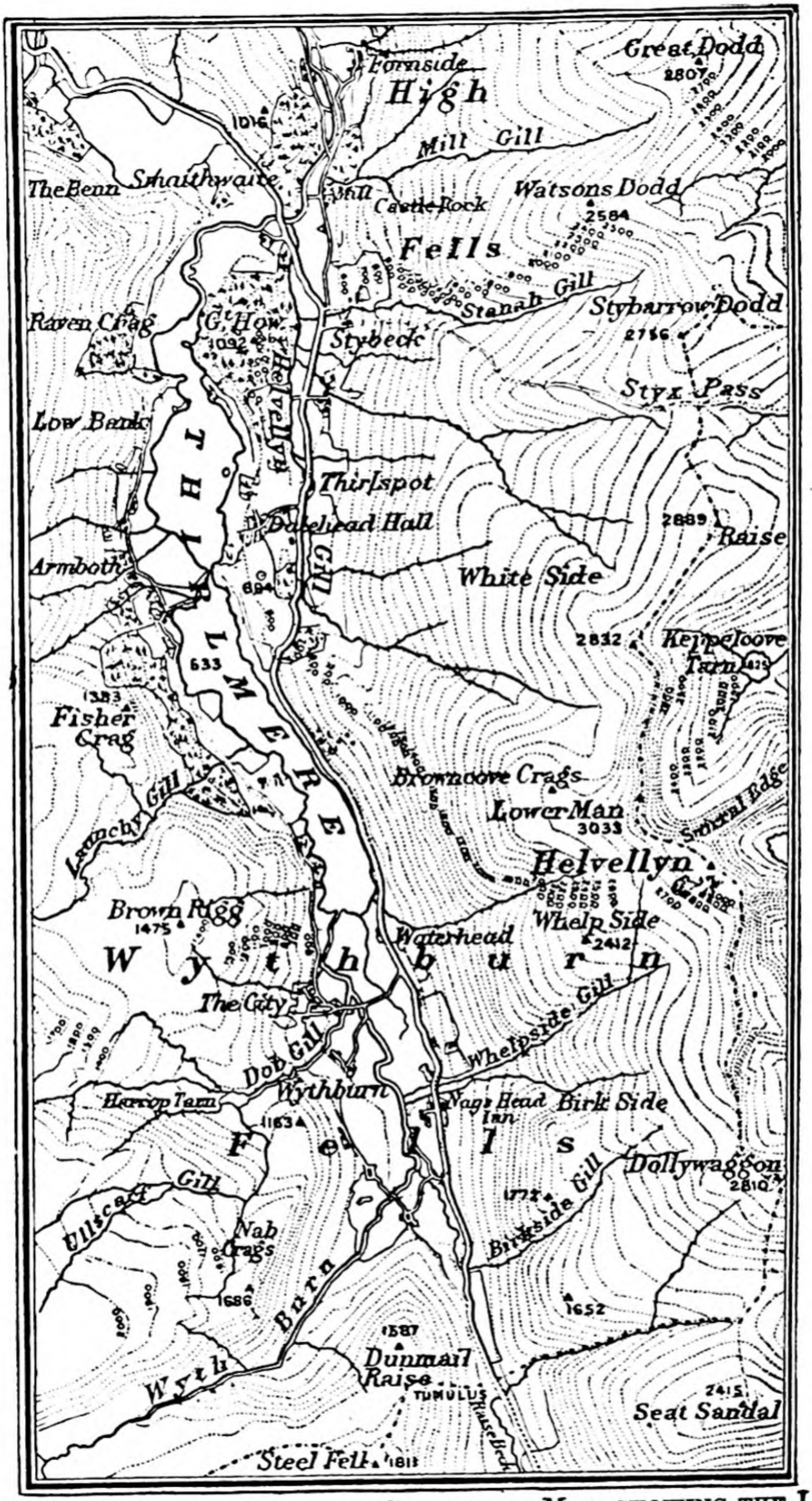
MAP 9.—PART OF A ONE-INCH ORDNANCE MAP, WITH CONTOURS AND HACHURES (OLD UNCOLOURED EDITION).

the main road from Lancaster. The highest ground is 1,184 feet on Caton Moor. Find the 100 feet contour on each side of the river and follow it as far as you can (a magnifying glass is useful in following the

fine contour lines). On the south side of the railway find the 200 feet contour and the successive contours up to 1,000 feet. The last two may be followed all round. On which side of the summit of Caton Moor do the hachures indicate the steepest slope ? Follow the road from Hornby to Back Farm on the west side of Caton Moor. Is it a first-class road all the way ? Is there any footpath from the road to the summit of the Moor ? Do not confuse the symbol for a parish boundary with the symbol for a footpath. How would you get by road from Melling to Wray ? What is the distance by road ? and in a direct line ? Note that the railway from Wennington passes along the valleys : for engineers endeavour to keep railways as level as possible. The branch of the railway that turns north-west after leaving Wennington passes through a cutting into a tunnel. How long is the tunnel ? What is the area of the flat land near the middle of the north end of the map ? Areas may be estimated by placing over the part to be measured a sheet of thin tracing paper on which are ruled squares one-tenth of an inch in side.[1] Is Caton Moor wooded ? Where are woods indicated ? Find the antiquities (names printed in Old English type) on the map. Draw a section from the highest point on Caton Moor to the hill 200 feet high near the north bank of the Lune. Find the relation between your vertical scale and the horizontal scale of the map.

The one-inch map of the Thirlmere Basin with contours but no hachures on page 142 shows a very different piece of country from that on page 140. What area does it represent ? The lowest land is near the middle at the north end, where a small stream called St. John's Beck is carrying off the waters of the lake to the north. The highest land is the summit of Helvellyn, 3,118 feet high. The height of the lake is given as 533 feet ; but, since the map was engraved, an embankment at the north end has raised the level of the lake 35 feet, so that it now occupies an area of 690 acres, its natural one being 300 acres. The lake can be raised to 583 feet, when it will spread out nearer the 600 feet contour line and occupy 793 acres. The water does not now pass into the stream until it flows over the embankment. The main portion of the water, indeed, is carried off by pipes to Manchester, for the lake is used as a source of water supply to that city. On the east side of the map are several spurs of high ground extending down towards the lake. Between the spurs are valleys down which streams run. Note how the contour lines run up the valleys down which streams pass. Some of these streams at the north-east end pass as tributaries, either directly or indirectly, into the river running from the lake. Others pass directly into the lake. A stream, Wyth Burn, flows northward to enter the south end of the lake. This stream receives other streams —Birkside Gill, Whelpside Gill, and Dobb Gill. A road from Grasmere begins at the south end of the map, passes Dunmail Raise (note trigonometrical point on summit there) along the east end of the lake, and leaves the map at the north-west corner to pass on to Keswick. A branch from the road near the wooded height, Great How, passes to the hamlet of Fornside. Follow, with the aid of a magnifying glass, the contour lines up the valley down which the Stanah Gill flows into a tributary of St. John's Beck. They rise from 600 feet by vertical intervals of 100 feet to 2,754 at the summit of Stybarrow Dodd. (On some one-inch

[1] Each square is $\frac{1}{100}$ of an inch in area : 1 sq. mile = 640 acres.



MAP 10.—PART OF A ONE-INCH CONTOURED MAP, SHOWING THE LAND AROUND LAKE THIRLMERE.

maps contours are shown at intervals of 100 feet from 100 feet to 1,000 feet, and after that the contour intervals are 250 feet.) Between this height and the Raise is a col or pass, the Styx Pass. An unmetalled road is shown leading over the pass from the lake valley road. Find the Nag's Head Inn at the village of Wythburn. What kind of a church is there in the village ? How far is it from the Inn to the top of Helvellyn ? Remember that distance on the map is distance on the horizontal scale without allowance for the vertical element. An inch on the map represents a mile in the horizontal direction, so that the actual distance one has to walk in a mountainous part will be somewhat more than the scale shows, even if the route is direct. Point out divides or water partings on the map. What kinds of roads are indicated on the west side of the map ? Since the map was prepared a fine new first-class road has been made on this side. Where is a county boundary indicated ? The county on the east side of it is Westmorland, Thirlmere being in Cumberland.

Fig. 84 shows a section across the map at the north end. Draw one from Keppelcove Tarn to Brown Rigg, using the same scale or

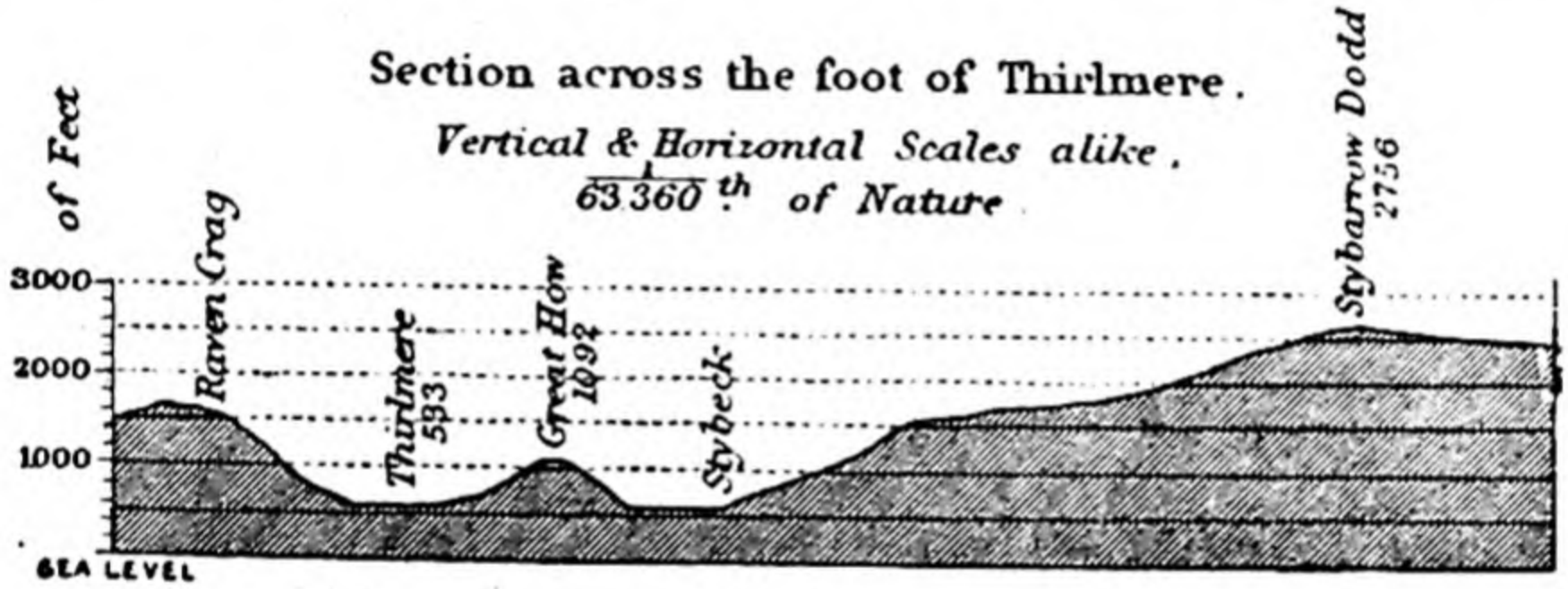


FIG. 84.

making the vertical scale about ten times the horizontal scale (*See* Glossary, 'Sea-level.')

The reader should now obtain the one-inch map of his own district, and also one or two of the six-inch maps that will include his district. The one-inch map will be about 27 inches by 18 inches, and show an area of 486 sq. miles. Six-inch maps, usually issued in quarter sheets, size 18 inches by 12 inches, include an area of $3 \times 2 = 6$ sq. miles only. Compare the areas represented on the different scales. Note on a six-inch map the increase of detail. The form and situation of buildings and fields, for example, are clearly indicated. Besides the contour lines, separate actual heights placed against a dot on a main road are frequent. Some heights are shown thus : B.M. 478.6. This denotes a height of the ground obtained by the survey officers and refers to marks called 'bench-marks' (a broad arrow ↑) cut on buildings, gate-posts, etc. Other abbreviations used on the six-inch map are explained in the pamphlet already referred to. A twenty-five inch map of part of the district included on a six-inch map should also be examined. The comparison of maps of the same part on different scales is very instructive. Bartholomew's contoured maps of the district will also be useful.

76*a*. **The Land Utilisation Maps and the popular Edition of the One-Inch Ordnance Map.**—The coloured frontispiece to this book is a

piece of one of these maps which was included in the 1939 General Schools Examination of the University of London. The *black outline* is prepared by the Ordnance Survey and the symbols used are in general similar to those on p. 138 and on Map 9. The *water* is shown in blue and the *relief* of the ground by contours (in orange) drawn at vertical intervals of 50 feet. Then the *use of the land* is shown by the colours indicated in the key. Some of the following questions on a section of a land utilisation map were set at the 1936 School Leaving Certificate Examination of the Northern Joint Board (they can be applied also to the map in the frontispiece, and in brackets are appended partial answers) :—

(*a*) Explain very briefly the meaning of the following terms used in the map-index :

(i) arable land (= land ploughed by the farmer and used for growing crops)

(ii) permanent grassland (= land covered with grass and which is not ploughed but is carefully tended by the farmer and used for grazing his animals or for hay).

(*b*) The upland area is a chalk land. State two ways in which the map appears to indicate this fact (by the name ' down ' ; by the presence of dry valleys).

(*c*) How does the grassland in the south-west differ from that in the north of the area ? (it is hill pasture, on hilly rolling country and there are patches of poor rough pasture shown in yellow and sometimes scattered bushes, but there are no streams or ponds in the southern area. In the north it is on lower, flatter ground and is well watered and probably richer).

(*d*) Describe briefly the general distribution of arable land of the area (some on the chalk downs ; a broad belt on the shelf at the foot of the downs ; a few fields on the lower, wetter ground of the north).

(*e*) With regard to the town of Lewes :

(i) describe its communication facilities by road,

(ii) state the chief features of its position (a typical gap town on a small navigable river).

77. **Isotherm and Isobar Maps.**—Temperature observations are made at numerous places on the earth daily, and from these the average temperature for any month or year can be obtained. Such observations and calculations have been made during many years. As temperature diminishes with height above sea-level (a fall of 1° for about every 300 feet above sea-level) all temperatures are reduced to sea-level for the purpose of marking the isotherms on maps. If then we had the mean average temperature for some hundreds of places marked on a map of the world, we could draw the annual isotherms as on the map on page 87. To do this in the case of such a large area we should disregard all figures except those showing a difference of 10°. Near the equator we should find 80° very often, and drawing a line through all places marked 80° we should get the isotherm of 80°. Some distance north and south of the equator 70° would often occur. A line through the places marked 70° would give us the annual isotherm of 70° and so for 60°, 50°, 40°, 30°, 20°, and 10°. The temperature at the places between the isotherms is usually assumed to be proportional to the distances, so that, *e.g.*, a place one-fourth the distance from the isotherm 60° in the direction passing to 50° would have a mean yearly temperature

of 57½° provided it was situated at the sea-level, for, as just said, isotherms are constructed to refer to sea-level. If the place were above sea-level we should deduct 1° for every 300 feet of height. Thus all places on a contour line of 600 feet would require a deduction of 2°, and places on a contour line of 2,000 feet would require a deduction of about 7°, from the temperature indicated by the isotherms.

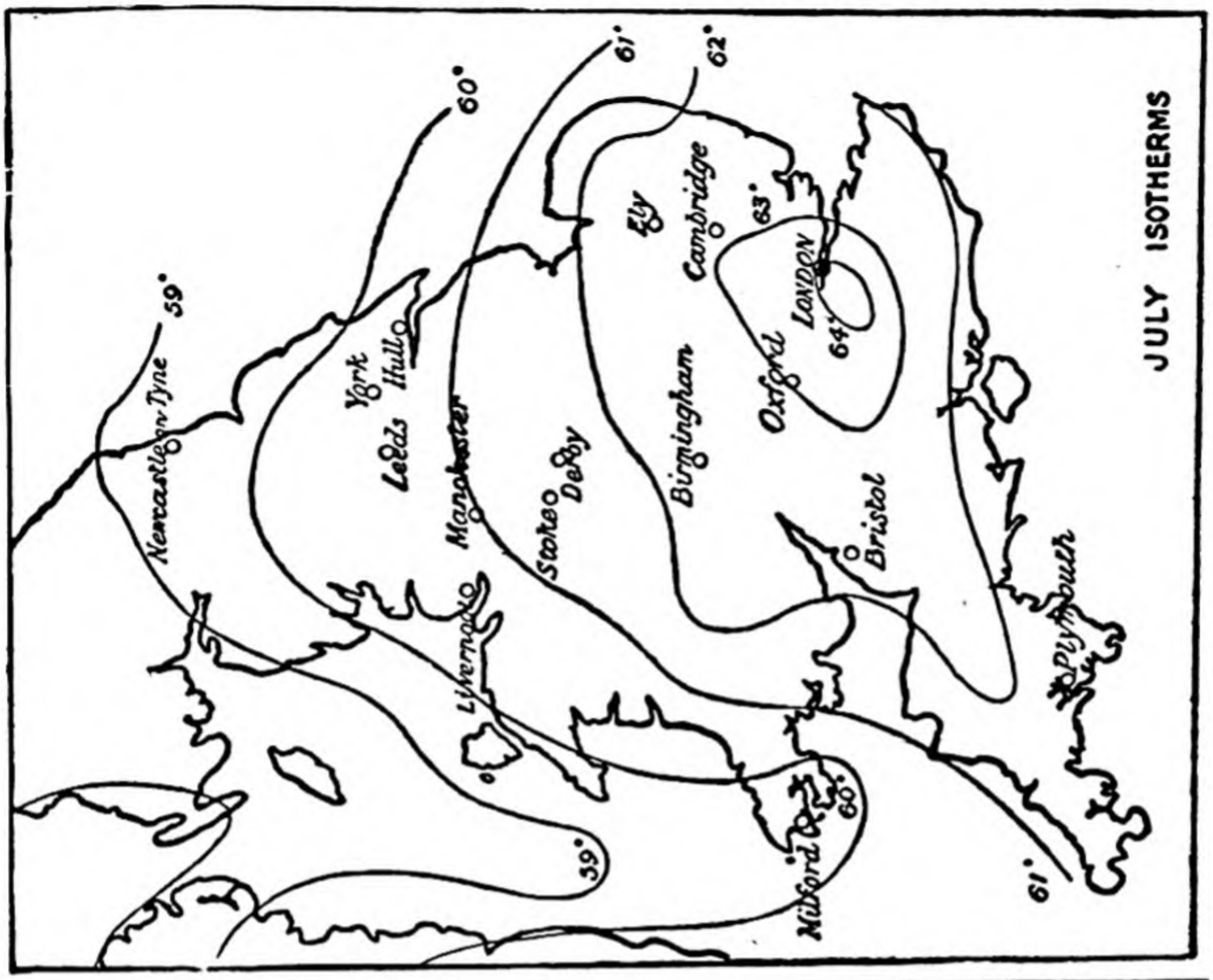
The maps on pages 31 and 32 were constructed in a similar way. For a smaller area we could use our average temperature for any period to indicate a difference of 1°. See the maps showing the January and July isotherms for England. These maps show us that, on the average, the west side of England is warmer than the east. But why do the January isotherms run nearly north and south and the July isotherms nearly east and west? In January the sea is warmer than the land, and the west side of the country receives the warmer winds from the sea in greater quantity than the east. In July the land warmed by the summer sun is warmer than the sea from which the prevailing winds come. The July isotherms in fact rise towards the east, and it is then as warm in Durham as in South Wales.

From what has been said above about the construction of isotherm maps from temperature data, we can easily understand how isobar maps are constructed from data giving barometric pressures in various places. Remember, however, that for the purposes of comparison all barometric observations are first reduced to sea-level. With a number of points at which such reduced barometric pressures were recorded, isobars could be drawn through the points having the same pressures. If the numbers varied slightly you would pass a little to one side or other as general consideration of the numbers indicated.

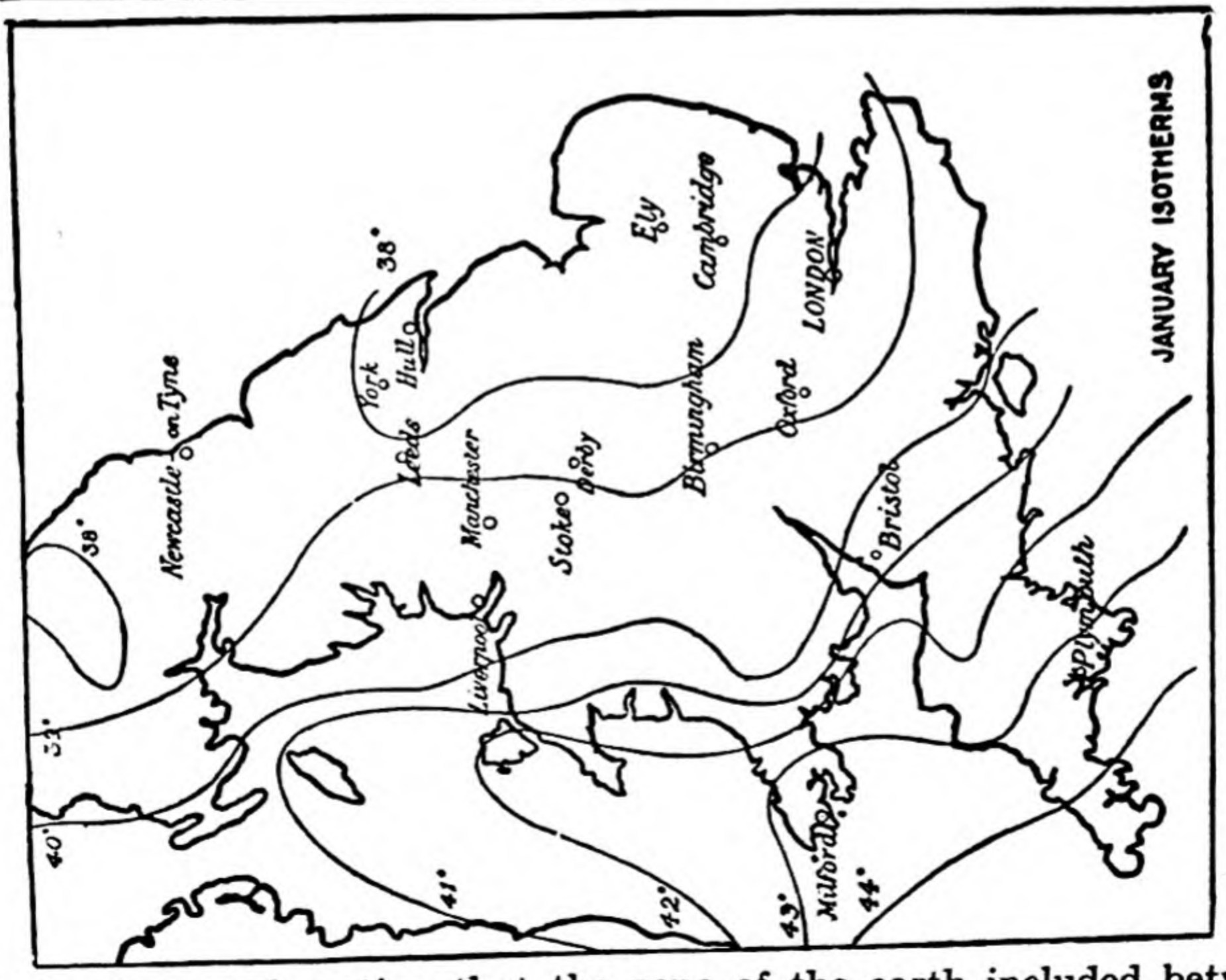
78. **Globes.**—A terrestrial globe is an artificial sphere on which are drawn lines of latitude and longitude, and also a representation of the surface of the earth. The globe represents the earth as a perfect sphere, for its size compared with that of the earth does not permit it to show the small difference (13 miles) between an equatorial and a polar radius. Its surface, too, is represented as smooth, since the highest mountains become insignificant on the small scale of the globe.

The lines of latitude and longitude may be put in for every degree, or even for parts of a degree, if the globe is a large one. They are, however, often put in for every 5° or 10° only. We must note that all the meridian lines pass through the poles and are 'great circles,' for they divide the globe into two equal hemispheres. The length of a degree on a meridian, or any other great circle of the globe regarded as a sphere, is 60 geographical miles or 69¼ statute miles (*see* Glossary, 'Mile'). One of the meridians, that passing through Greenwich, is the zero or initial meridian from which longitude is reckoned east or west in degrees. All the parallels of latitude, except the equator, are 'small circles' and become smaller and smaller as they approach the poles. Latitude is reckoned north or south of the equator in degrees. Since a degree may be regarded as the 360th part of a circle, it is clear that the length of a degree on a small circle is less than one on a large circle. A degree of longitude, therefore, that is the distance between two meridians 1° apart, gets less and less as we approach the poles. At lat. 60° the 'small' circle forming the parallel of latitude is in length one-half the equator, so that one degree at this latitude is only half the length of one at the equator. Hence an area of the earth included between 1° of long. and 1° of lat. near the equator is twice as large as a similar area near lat. 60°. In higher latitudes the difference is still greater.

Notice on the globe the size of the trapezoid spaces enclosed between the lines of latitude and longitude at various distances from the equator.



MAP 12.



MAP 11.

It is also worth noting that the zone of the earth included between lat. 30° N. and 30° S. embraces one-half of the surface of the earth, the

two remaining portions of the globe, one stretching 60° in lat. to the north and the other 60° lat. to the south, form the other half of the surface.

The chief points of coast lines, the positions of mountains, hills, rivers, towns, etc., are fixed by astronomical observations and trigonometrical surveying, and these are then put in their proper positions on a globe provided with lines of latitude and longitude. Other details are supplied by local surveys.

It is advisable to refer to a globe frequently to keep correct ideas of the relative size, shape, and position of the various continents, countries, and islands, for no map on a flat surface can represent a large area correctly, as we shall presently learn. The places (towns, capes, bays, etc.) through which some of the more important lines of latitude and longitude pass should be noted. An artificial globe is made so as to revolve on an axis representing that of the earth. It moves in a brass vertical circle divided into degrees, and this serves as a general meridian. Round the centre of the globe is a horizontal wooden circle that serves as a rational horizon. The axis of the globe can be placed in any position, so that any point on the surface of the globe can be brought to the highest point. Many interesting and useful problems can be solved by the aid of such a globe. The distance apart of two places can be found by measuring the number of degrees on a *great circle* between them and multiplying this number by 69¼. For this purpose a quadrant of thin brass that fits the globe is often provided. In the absence of a quadrant take the distance between the two places with a pair of compasses and apply this distance to the equator. This will give the number of degrees between them. The distances measured on the globe may be transferred to a map, for distances on *maps* of hemispheres or other extensive areas cannot be estimated from a scale, except along the equator or central meridian, since all such maps, as will be shown in the next chapter, are exaggerated or distorted at certain parts. On maps of small area, as the Ordnance Survey maps, distances can be estimated from the scale, as they are correct in all parts. Another use of the globe and the quadrant is to find the direct and shortest route between two places on the great circle between them. Compare the distance of two places in lat. 50° far apart as measured along the parallel of latitude between them and along the great circle between the two places (*see* 'Great Circle Sailing' in Glossary). For further information, *see* Johnston's *Handbook to the Terrestrial Globe*. We now proceed to consider how to transfer the network of lines of latitude and longitude from a globe to a flat surface, so as to form a map, a branch of study called Map Projection.

CHAPTER XI

METHODS OF MAP PROJECTION

79. Globes and Maps.—A true representation of the features of the earth's surface can be made only on a globe or sphere, for in this way alone can be got a representation of the curvature of the earth's surface, and of the relative positions and sizes of its countries and seas. But although globes are so

useful in giving a true indication of the relative position and sizes of the *large* continents and oceans, they would require to be very big and costly if we wished to mark on them the details of separate countries like England.

For example, the area representing the British Isles on a globe of two feet diameter would be only about one square inch, so that few towns, rivers, and mountains could be indicated upon it. Further, globes are inconvenient to carry about. Hence maps are drawn, on which countries can be represented on a much larger scale than on a globe, and which can be readily moved and put away. Now maps are representations of the earth's surface, or a part of it, upon a plane or flat surface (Par. 45), and in one sense they are therefore not true representations of the earth's curved surface. Besides, a curved surface cannot be made into a plane surface without some distortion, as the following simple experiments indicate :—

(*a*) Take half the rind of an orange in its original hemispherical shape, and try to spread it out flat. It will split at the outer edge, though the middle part may be made to lie flat.

(*b*) Take half a hollow indiarubber ball, and with the help of drawing-pins spread it out as a flat circle. This can be done by stretching all the outer portions. Note the change of appearance of any marks or outlines made on the surface of the ball. If they are near the centre of the surface they will appear much the same whether the rubber be spherical or flat ; but if the marks are near the edge they suffer distortion when the rubber is stretched to make it lie flat.

In representing the spherical surface of the earth upon the plane surface of a map various methods are employed, some distorting countries in one way, and some in others ; some being suitable for a whole hemisphere, and others suitable for smaller parts, like separate continents or single countries. Some of the methods employed are perspective projections of the earth, or a part of it, on a plane surface ; that is, such a method is a representation of the earth's surface as it would appear to an eye placed in a certain position with regard to this surface. The plane surface on which the representation is made is called *the plane of projection*, and the process of projection consists essentially of drawing lines from points on the surface of the globe to the point of view, making them meet the plane surface on which the map is to be drawn. The important thing is first to transfer, in the above way, to our flat map the circular parallels of latitude and meridians of longitude from the spherical surface, and then, knowing the latitude and longitude of the various places, these places can be filled in. Remember that on a globe the parallels of latitude are really *small* circles of the sphere parallel to the great circle called the equator, and that they get smaller and smaller as they approach each pole ; while the meridians are all *great* circles, getting nearer and nearer together as they approach to meet at each pole.[1] (We are at present regarding the earth as a true sphere in shape.) On the flat maps projected from the sphere, these lines will usually be curves, though not necessarily parts of a circle. The actual shape of the lines will depend on the method of projection, as will now be seen.

---

[1] *See* Glossary, ' Sphere.'

80. **The Stereographic Projection.**—The stereographic projection of a hemisphere represents it as it would appear to an eye placed on the centre of the surface of the opposite hemisphere; *i.e.* to an eye placed at the antipodes of the hemisphere represented. The globe is supposed to be transparent, and the plane of projection may be supposed to be the circular transparent plane surface bisecting the globe between the observer and the opposite hemisphere. Each point on the distant hemisphere is then transferred to this plane of projection by a line drawn from the point to the observer's eye, so that on this transparent plane the parallels, meridians, coast line, rivers, towns, etc., of the hemisphere opposite the eye are projected, and may be marked much in the same way as an object outside a room could be delineated on a window. Fig. 85 is a section of the globe and of the plane of projection AB. By its help we can see that equal distances on the surface of the hemisphere projected are not equal on the plane of projection, but increase in size as we pass from the centre of the hemisphere towards the outside, where they become spread out considerably.

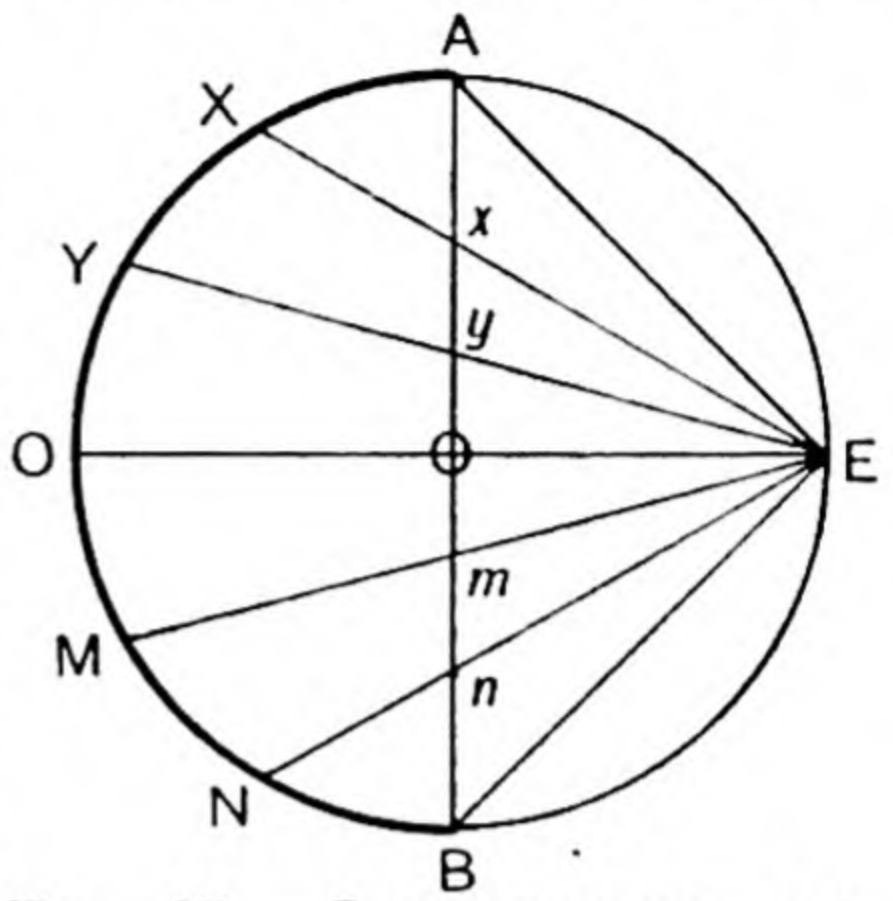


FIG. 85.—ILLUSTRATING THE STEREOGRAPHIC PROJECTION. E, position of eye; AB, plane of projection seen in section as a line; AX, XY, YO, equal distances on the hemisphere seen as Ax, Xy, and yO on the plane of projection.

FIG. 86.—THE EASTERN HEMISPHERE ON THE STEREOGRAPHIC PROJECTION.

Putting the same truth in another way, we see in the *lower* part of the figure that equal distances on the plane of projection do not represent equal distances on the globe, but represent less and less as we pass to the edges of the flat map. There is least distortion near the middle.

The annexed map of the Eastern hemisphere represents the network of meridians and parallels obtained in the stereographic representation of this half of the globe, the complete map being bounded by a circle. It shows also how the meshes thus formed increase in size as we pass from the centre to the outside, although each mesh in

the same latitude really represents an equal area on the globe. The outside countries and seas are thus distorted, both in size and shape, though the middle of the map suffers but little distortion. But the lines cutting one another on the globe cut one another at the same angle on the map, and hence the stereographic projection is an *equiangular* projection.

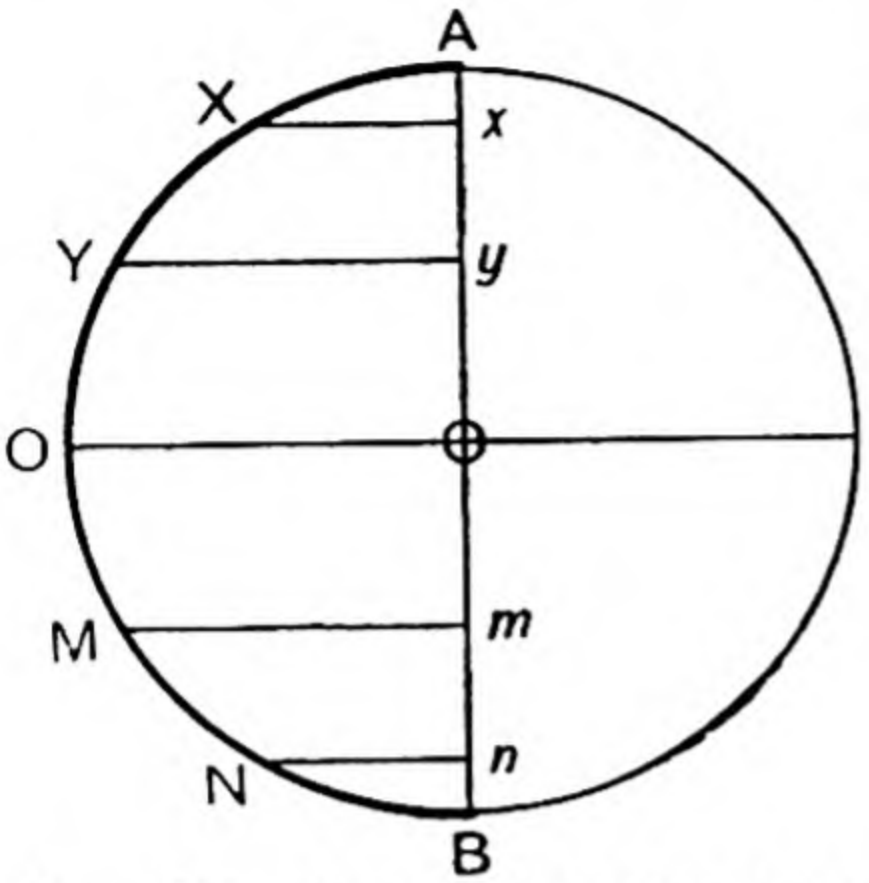


FIG. 87.—ILLUSTRATING THE ORTHOGRAPHIC PROJECTION ON THE PLANE OF PROJECTION AB. Upper part shows how equal distances on the hemisphere become crowded towards the outside of the plane of projection.

81. **The Orthographic Projection.**—In the orthographic projection each hemisphere is shown as it would appear to an eye supposed to be at an infinite distance from the globe. According to the laws of perspective, all lines drawn from points on the globe to such an observer would appear parallel. To project, therefore, points on the surface of the hemisphere opposite the observer upon a plane surface passing through the centre of the globe, we draw parallel lines from these points at right angles to the plane of projection. An examination of this projection shown in section in fig. 87 illustrates how equal distances on the globular surface still become unequal on the plane of projection, that only the central portions of the globe are well represented, and that the outlying portions become so crowded together and diminished as to produce great distortion. This projection is, in fact, but little used for geographical maps.

82. **The Globular or Equidistant Projection.**—In order to remedy the opposite defects of the stereographic and orthographic projections, another projection is employed, in which the eye is supposed to be in a position which will preserve the relative dimensions of the objects on all parts of the hemisphere delineated. This projection is called the globular or equidistant projection, and is that usually employed in representing the hemisphere in atlases, as it preserves the relative areas of the different countries well, though not their shape. The position of

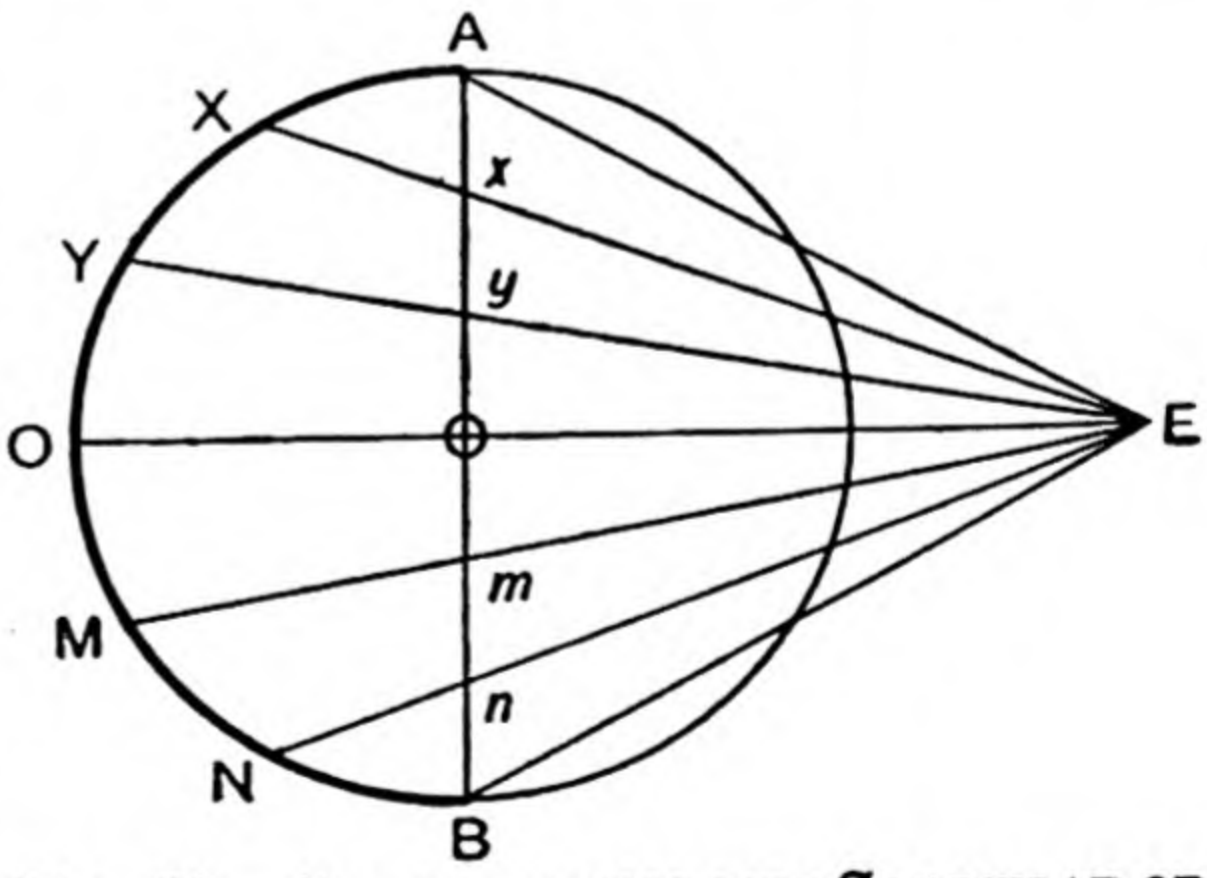


FIG. 88.—ILLUSTRATING THE GLOBULAR OR EQUIDISTANT PROJECTION. E, position of eye; AB, plane of projection seen in section as a line. In the upper portion of the hemisphere equal distances on the hemisphere are seen projected on AB; in the lower part equal distances on AB are shown to represent unequal distances on the hemisphere.

the eye for the globular or equidistant projection is on the diameter of the sphere perpendiu lar to the plane of projection, at a distance from the surface of the sphere = radius $\times \frac{\sqrt{2}}{2}$.

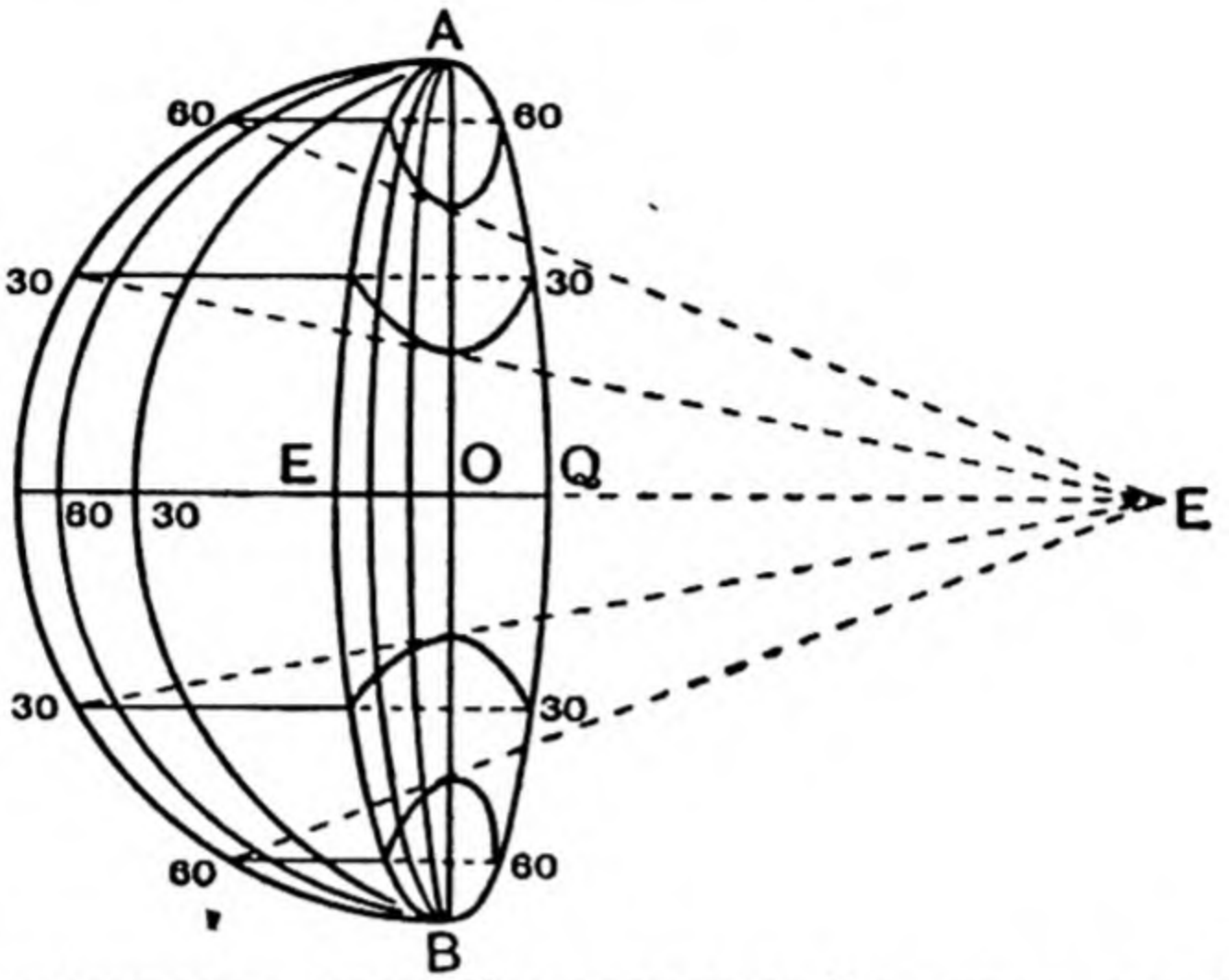


FIG. 89.—ILLUSTRATING HOW PARALLELS OF LATITUDE AND MERIDIANS OF LONGITUDE ARE OBTAINED ON THE EQUIDISTANT PROJECTION.

By the help of fig. 88 it is seen that equal distances on the surface of the hemisphere are represented by nearly equal distances on the plane

FIG. 90.—THE EASTERN HEMISPHERE ON THE GLOBULAR OR EQUIDISTANT PROJECTION.

of projection, and *vice versâ*. With the help of fig. 89, which shows the circular plane of projection viewed sidewise as an ellipse, the reader

will be enabled to understand this method of projection more clearly. To avoid confusion we only show the parallels and meridians at intervals of 30°. The equator and central meridian are projected upon the flat surface as straight lines cutting one another at right angles at the centre of the map. The lines of latitude become curves bending towards the equator, and the lines of longitude or meridians start from the poles and bend away from the central meridian. When both parallels of latitude and meridians are fully drawn on such a plane of projection we get the complete hemisphere bounded by a circle, and the appearance represented in fig. 90. We see that the meridians are all the same distance apart at the equator, and that they approach equally as they pass towards the poles, just as on the globe. The parallels are also all the same distance apart at the central meridian, but as they approach the outside of the map they get wider apart, so that the map thus obtained is somewhat distorted at the edges, and the lands and seas have there not quite the same shape as on the globe. Still, by comparing fig. 86 and fig. 90, we see that there is not in the globular projection so much enlargement and distortion on the outsides as in the stereographic projection. It should be understood that any great circle of the globe may be chosen for the plane of projection. When the meridian circle 20° W. of Greenwich is chosen, we get a map of the world divided into Eastern and Western hemispheres (*compare* fig. 35). When the equator is chosen for the plane of projection we get a map of the world divided into Northern and Southern hemispheres. When we take the great circle 90° from London (the plane of the rational horizon of London) for the plane of projection we get a hemisphere of greatest land and another of greatest water (fig. 36).

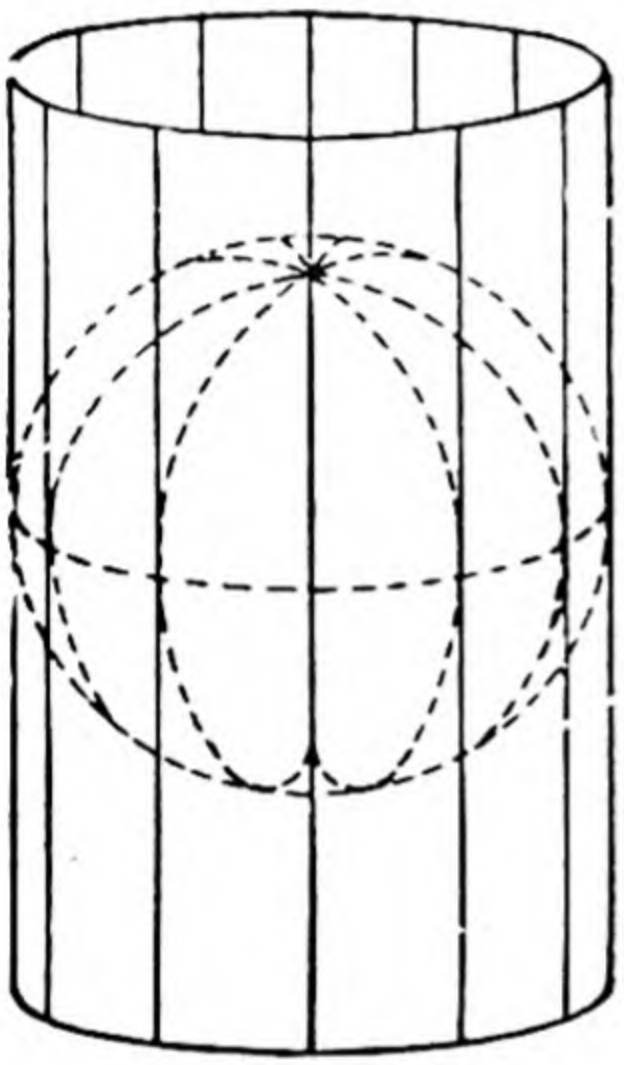


FIG. 91.—CYLINDER SURROUNDING A GLOBE.

83. **Mercator's Projection.**—When it is desired to obtain a representation of nearly all the earth on one map, a method of projection and development known from the name of its inventor as the *Mercator projection* is commonly employed.

In Mercator's projection a hollow cylinder is supposed to surround a globe, touching it all along the equator, as shown in fig. 91. To get an idea of how the map will arise an old writer says: 'Conceive the surface of this globe to swell from the equator towards the poles, proportionally in latitude as it does in longitude, until every part of its surface meet that of the concave cylinder, and impress on it the lines that were drawn on the globular surface.' On opening out the cylinder into a plane we get a network of lines at right angles to each other, representing the circles of latitude and longitude of the globe. To further illustrate this projection consider fig. 92, where the cylinder and globe are shown in section. It is easy to see that the equator will be transferred as a circle on the surrounding cylinder at the touching surface all round. By drawing lines from the centre of the globe through the various parallels in the figure through 15°, 30°, 45°, etc., to the cylinder, it is seen that these parallels are also transferred to the cylinder as circles, but that they spread apart more and more, so that the distance

between 30 and 45 is not nearly so great as between 45 and 60. The distance between 60 and 75 becomes much greater still, while the pole cannot be transferred to the cylinder at all. It is thus clear that the sizes of countries and seas towards the north and south are greatly exaggerated in length. Consider now the meridians. It is plain that these would be transferred to the cylinder by equidistant straight lines running lengthwise along the cylinder, though the meridians in reality get nearer and nearer as they approach the poles. Hence it is plain that towards the poles there will also be exaggeration in an east and west direction also. As there is such great exaggeration of the countries and seas towards the north and south, it is not usual to draw this map beyond 80° of latitude. If, now, the cylindrical roll be spread out or developed by cutting it along a meridian, we get a rectangular plane, on which the meridians are equidistant straight lines perpendicular to the equator, and the parallels straight lines parallel to the equator, but of increasing distance from each other for the same number of degrees of latitude. The whole network of lines when spread and flat is shown in fig. 93, where the lines are 10° apart, and the meridian 70° W. of Greenwich is the central meridian.

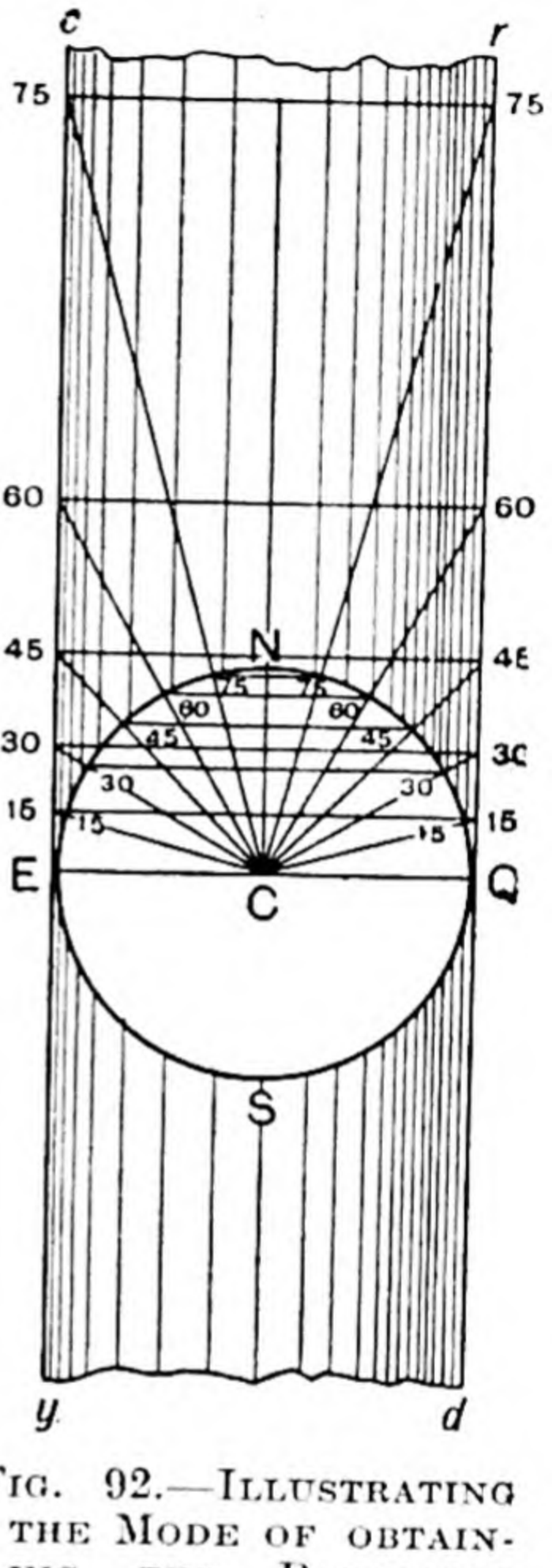


FIG. 92.—ILLUSTRATING THE MODE OF OBTAINING THE PARALLELS AND MERIDIANS ON THE CYLINDRICAL PROJECTION. (*See* Ques. 135.)

It will now be clearly understood that a map on Mercator's projection greatly exaggerates areas in the Polar regions, though the form of the countries is preserved. On Map 5 or 6, Greenland appears to be about as long from N. to S. as South America, though it is in reality only about 1,400 miles long, while South America is about 4,000 miles long, as the number of degrees of latitude covered by each shows (1° of lat. = 69¼ miles nearly). On the globe the parallels or circles of latitude become smaller and smaller as they approach the poles (Par. 3); but every parallel is crossed by 360 meridians of longitude, so that the distances between these latter, *i.e.* the distances corresponding to one degree of longitude, decrease from 69¼ miles at the equator to 0 at the poles. For instance, it will be seen that though Greenland and South America cover about 45° longitude from east to west, yet the actual breadth of Greenland is much less than that of South America. The area of Greenland is, in fact, only about one-tenth that of South America. A map on Mercator's projection cannot therefore be used to compare the areas of countries in different latitudes. Yet this projection is very useful for showing *relative directions* on different parts of the earth. Hence it is often used for indicating the direction of ocean currents, winds, isotherms, etc. It is used in *navigation by*

compass, as the course of a ship from one point to another can be represented by a line cutting the meridians at the same angle. (*See* Map 2.)

84. **The Conical Projection.**—The projection mostly used for maps of

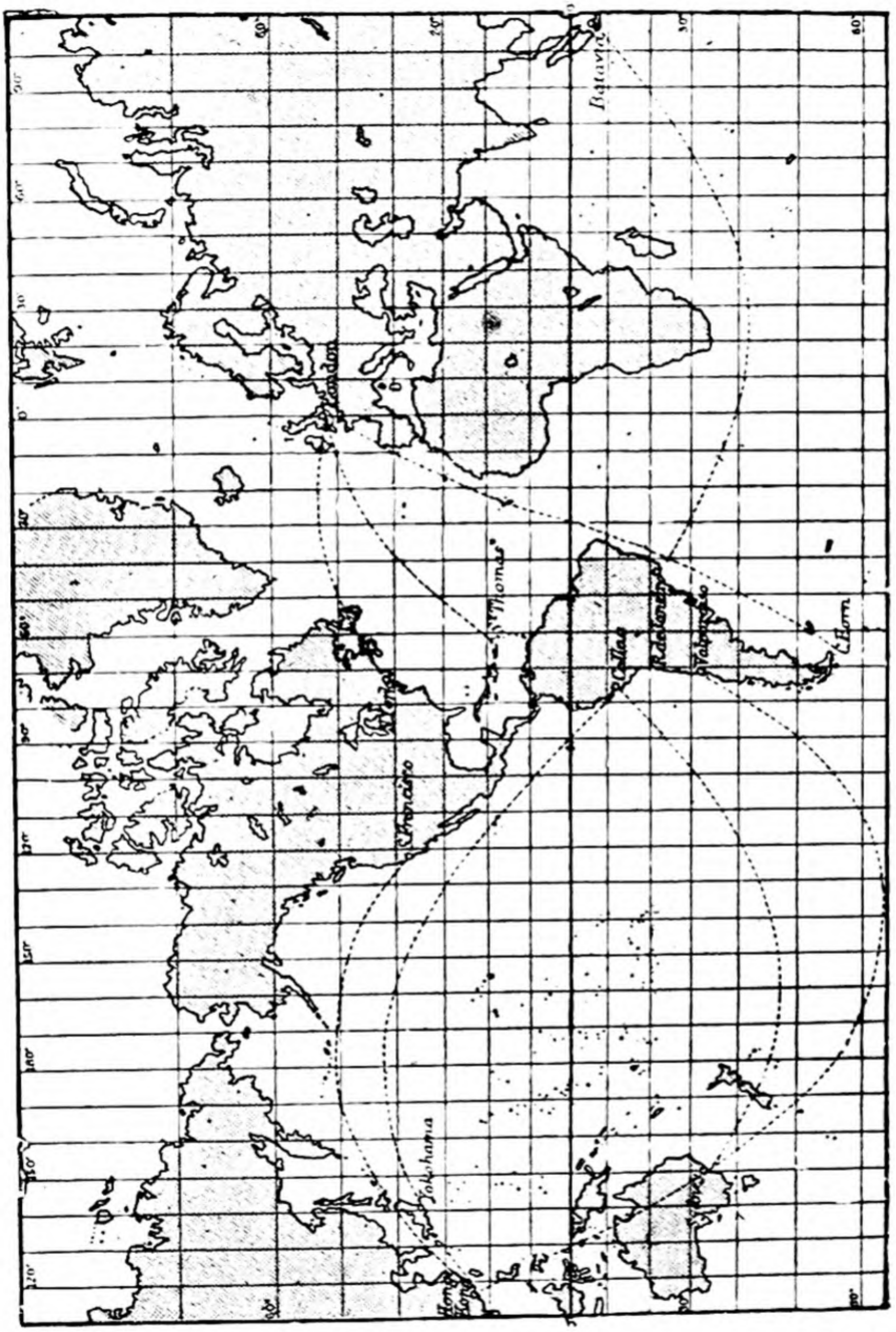


FIG. 93.—THE WORLD ON MERCATOR'S PROJECTION.

The curved lines are parts of great circles on the sphere, and therefore show the shortest sailing paths from one port to another. (*See* Glossary, 'Great Circle Sailing.')

the continents and *separate countries* is the conical projection, because it represents these smaller areas with the least distortion of parts. Imagine a cone touching the earth on the circle of latitude which passes through the middle of the country required to be drawn. Project from the centre of the globe the lines and parts to be included on the map to the inner surface of the enveloping cone. Now divide the cone along

two meridians that include the country to be represented, and spread out the surface flat. It will then be noticed that (1) the meridians or lines of longitude are straight lines converging towards the north in the Northern Hemisphere, or towards the south in the Southern Hemi-

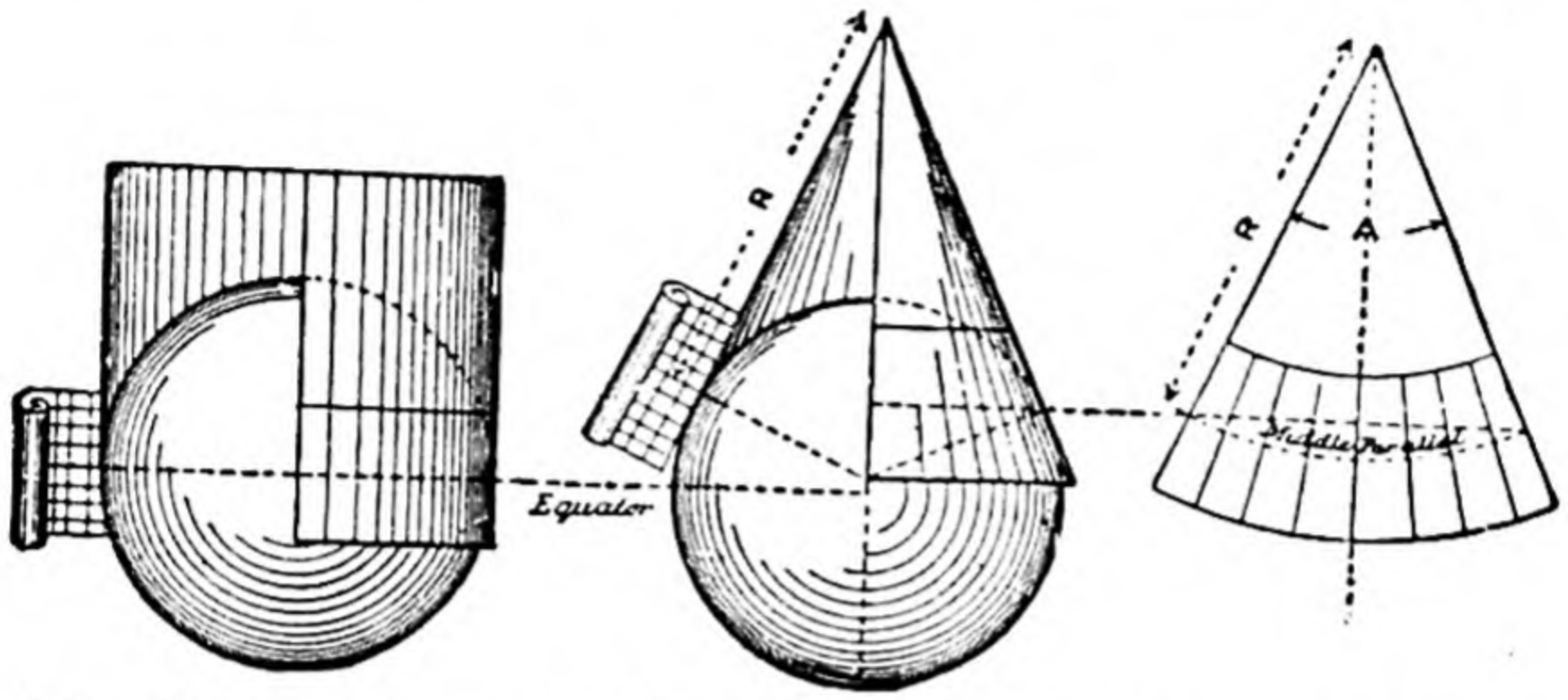


FIG. 94.—ILLUSTRATING THE CYLINDRICAL AND CONICAL PROJECTIONS AND DEVELOPMENTS.

sphere, as the meridian circles do on the globe ; (2) that the lines of latitude are arcs of circles with the apex of the cone as centre. As already remarked, the cone should touch the sphere about the middle latitude of the country to be represented. England, therefore, is best represented by a cone touching the sphere at lat. 53° N. In a map of the British Isles the middle latitude is about 55° N. For a map of Asia as represented in fig. 95, a good parallel is 40° N., as the exaggerations and distortions are then thrown upon the less important north of Siberia and the seas of the south. In the case of a map of a smaller area, like England or the British Isles, the lines of latitude are more nearly straight, and the lines of longitude more nearly parallel, than in a large area like Asia. (*See* Map 7.)

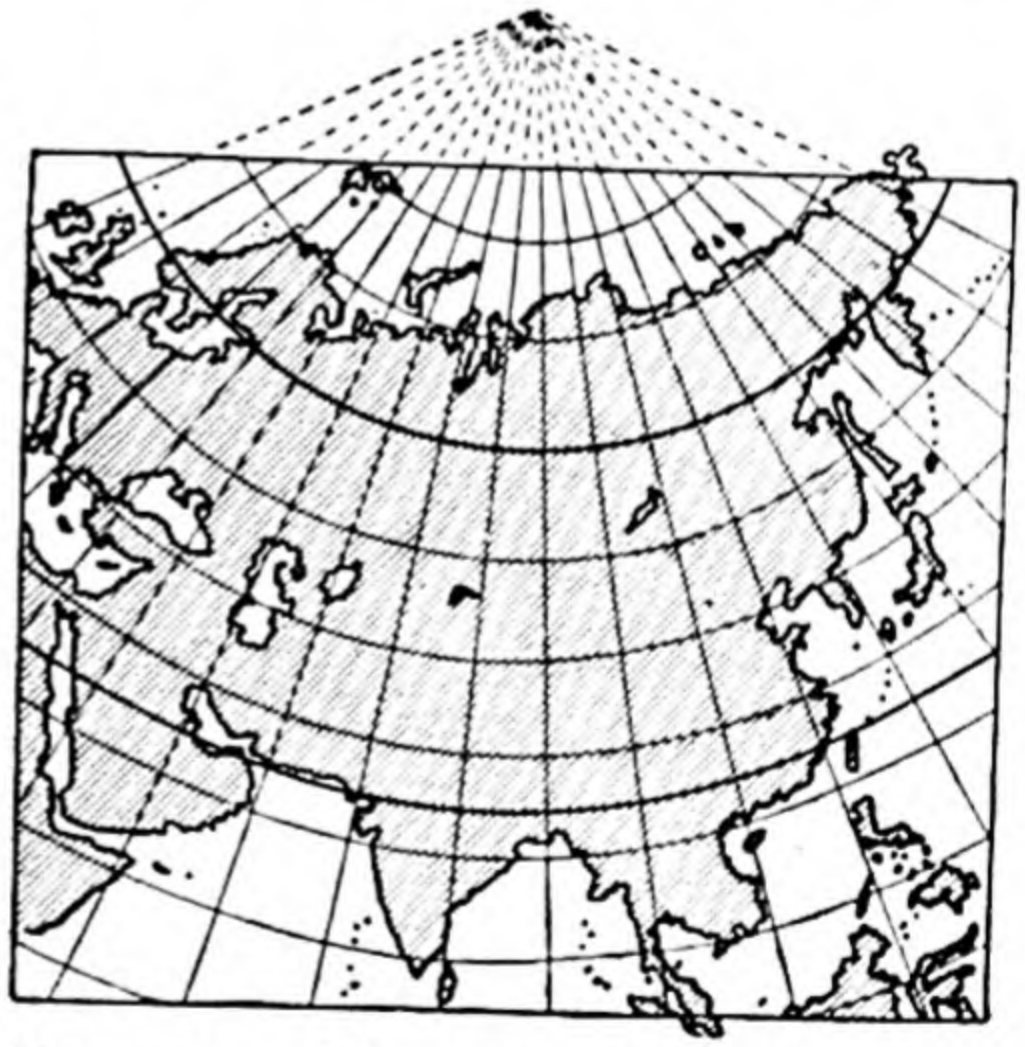


FIG. 95.—MAP OF ASIA ON THE CONICAL PROJECTION. (MERIDIANS CONTINUED TO APEX OF CONE.)

The great advantage of the conical method of projection is that there is no distortion at the edges of the map, as each mesh of the network obtained is exactly of the same shape between the same latitudes. Various slight modifications of the method are sometimes used in order to increase the accuracy of the representation obtained by it.

85. **Equal Area Projections.**—Projections have been devised that preserve the true relation of areas so that the areas of any two portions of a map have the same ratio to each other as the areas of corresponding

portions of the globe. Such maps are known as equal area maps. Though correct as to relative areas and useful for the purpose of comparing areas and for seeing the true extent of currents, winds, etc., they distort the shapes of the land, especially in the outer parts. For the whole world or very large areas Mollweide's equal-area projection, called also the homalographic projection (Greek, *homalos*, even), may be described. An ellipse is drawn with an area equal to that of a sphere. The central meridian is drawn as a straight line of the true length. The equator is also a straight line twice the length of the central meridian and is the long axis of the ellipse. The parallels of latitude are then drawn as straight lines parallel to the equator and at such distances (obtained by calculation) that the areas between them are equal to the corresponding belts of the sphere. This causes the parallels to get nearer as they approach the poles. The meridians are drawn as ellipses with the line of the middle meridian as the common axis, and they pass through the equator divided into equal parts. In this way they divide the areas between the parallels of latitude into equal parts. Fig. 96,

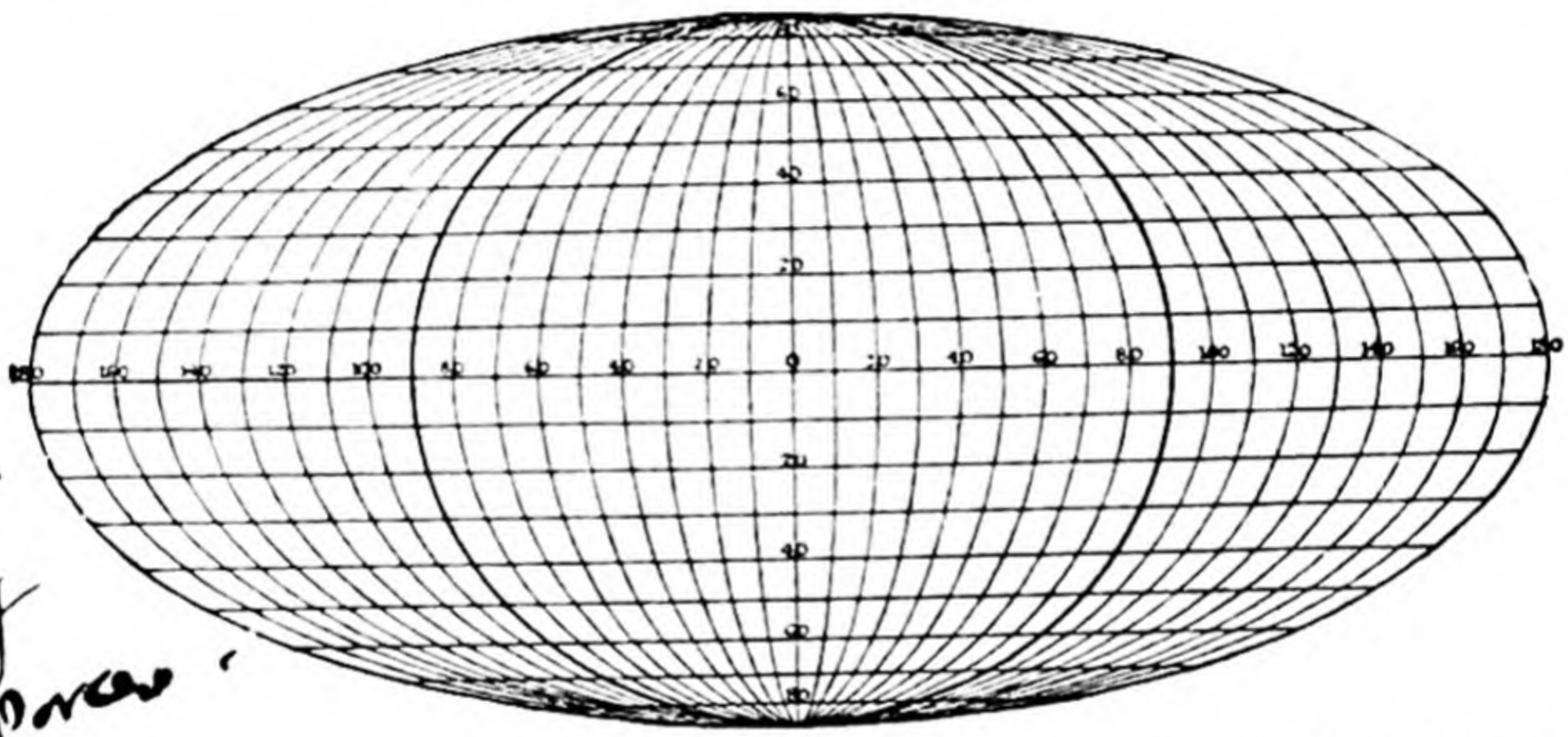


FIG. 96.—NETWORK OF PARALLELS AND MERIDIANS FOR MOLLWEIDE'S EQUAL-AREA PROJECTION.

though small, indicates the network of parallels and meridians obtained on Mollweide's equal-area projection.

86. From what has been said in the preceding paragraphs, we now see that no flat map of a large area can be accurate in all respects, since the relative sizes of the portions represented vary at different parts of the map; though a map of a small area like England is practically accurate on the conical projection. Each of the projections of large areas has its advantages and defects, as has been pointed out, and it is well in looking at such maps to note the projection so as to be aware of these. Moreover, the scale on such a map, if given, is of little use except in the case of maps of equidistant projection, when a fairly accurate result may be obtained in measurement from the centre of the map. The distance required should be measured on a globe (Par. 78) where 1° may be taken as equal to 69¼ statute miles, and then transferred to the map. Even then no allowance is made for the increase in length of the arc of a meridian as we approach the poles, where the earth is somewhat flatter (Par. 11). On an Ordnance map, which covers only a very small area, distances and areas can be calculated from the scale.

CHAPTER XII

THE APPARENT MOTIONS OF THE STARS AND OF THE SUN

87. **General Remarks.**—We know that the true form of the earth is that of an oblate spheroid (Par. 11); but it differs so little from a sphere or globe that we may usually regard it as a globe. We live on the surface of this globe, and our bodies and all other objects on the earth's surface are drawn towards its centre by the force of gravitation (Par. 1). In every place down means towards the centre of the earth (Par. 1). The earth turns continually from west to east on an imaginary line passing through its centre called its **axis.** The two opposite points on the earth's surface at the ends of this axis are called **poles.** Round this axis the earth turns each day, but so smooth and uniform is this daily rotation of the earth on its axis that we are unconscious of the motion, and hence we imagine ourselves to be at rest while the heavenly bodies appear to us to move in the opposite direction, from east to west. These apparent daily motions of the heavenly bodies deserve careful study, for the apparent movements of the celestial bodies of which we are conscious can be used to teach us the real movements of the earth of which we are not conscious.

In a level district or upon the open sea an observer seems on cloudless days to stand at the centre of a vast circular surface or plane, and this plane appears to be the base of a huge vault that we call the sky or heavens. The sky is not a real object, but only an appearance that is due to the blue light that is reflected from the air to our eyes. The stars and other heavenly bodies are in reality at different distances, but these distances are all so great that our eyes cannot detect any differences, and hence we imagine them to be on the surface of a vast hollow hemisphere. At the centre of the base of this hollow hemisphere the observer stands, and the circular plane which forms this base and bounds the observer's view is called the *plane of the horizon*. On whatever part of the earth's surface we may be we have a similar horizon plane and see a similar hemispherical vault. We thus arrive at the idea that the earth is placed at the centre of a vast sphere, half of which is above any observer's horizon and half below. We call this sphere the *celestial sphere*, and imagine it to be so vast that the earth may be regarded as a mere point in comparison when we are considering movements and distances on the celestial sphere.

88. **Apparent Rotation of the Celestial Sphere.**—The earth or terrestrial sphere appears to be at the centre of the great sphere of the heavens called the celestial sphere, the observer on any open plain having on clear days a visible half of the

celestial sphere above his horizon, and an invisible half below his horizon. Each point and line on the earth can be supposed to have at a given moment its corresponding point and line on the celestial sphere. Thus, the axis of the earth prolonged northwards to the heavens gives us the north pole of the heavens, and the earth's axis continued beyond the south pole passes to the south pole of the heavens, *i.e.* the celestial poles are the points on the celestial sphere where the earth's axis produced both ways meets the heavens, and the celestial axis is the earth's axis prolonged to meet the sky.

The earth turns on its axis from West to East, and this causes the celestial sphere to appear to turn round on a prolongation of the earth's axis from East to West and to carry the sun and stars with it, for these

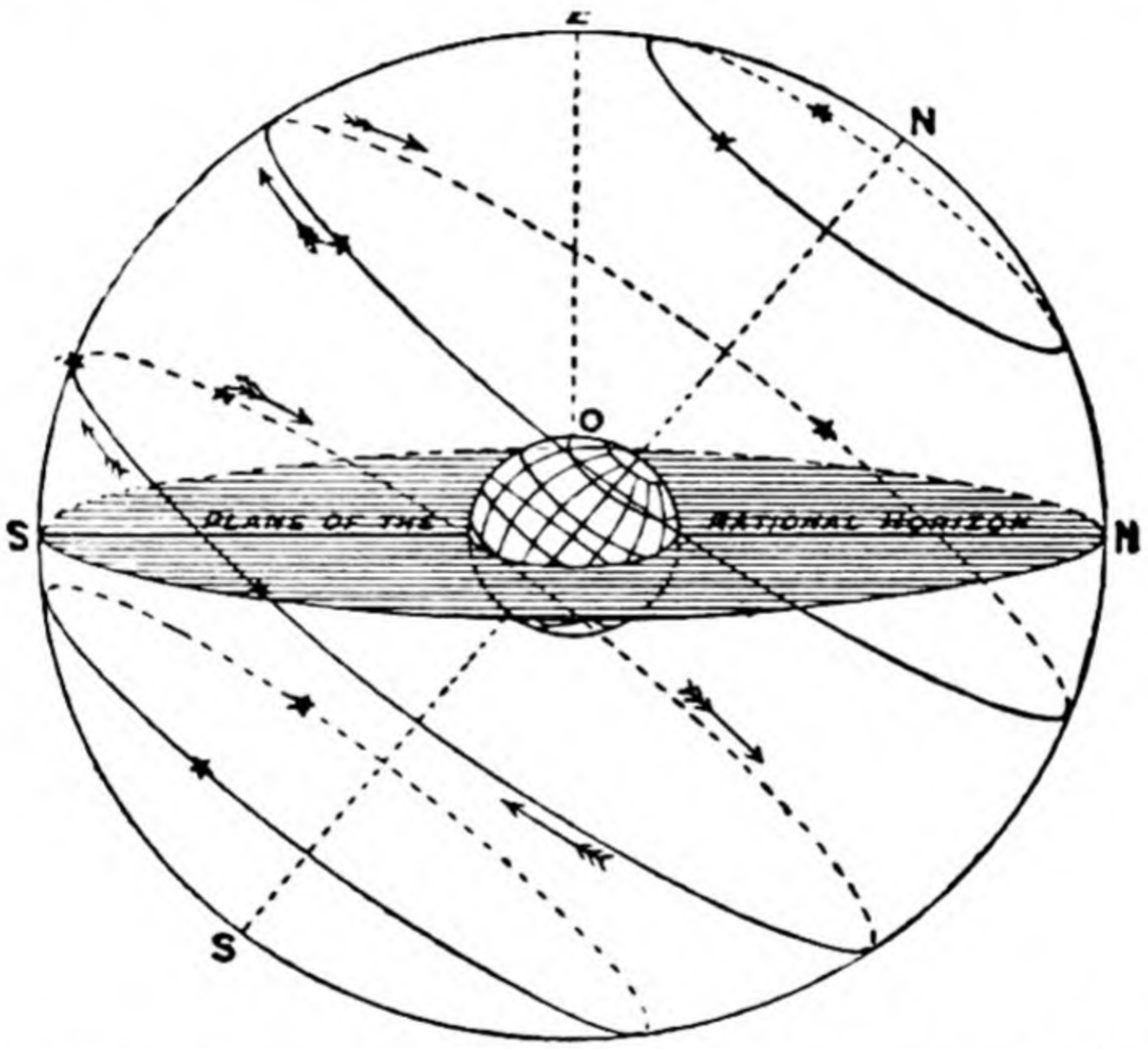


FIG. 97.—THE CELESTIAL SPHERE SURROUNDING THE EARTH, AS IT APPEARS TO AN OBSERVER SITUATED AT O. He has a sensible horizon that forms a tangent plane at O, but a rational horizon plane passing through the middle of the earth and parallel to the sensible horizon. Z is the observer's zenith. N S is the celestial axis about which the heavenly bodies appear to rotate in circles whose planes are at right angles to this axis.

heavenly bodies appear to be fastened on the inner surface of the celestial sphere, *i.e.* the real diurnal rotation of the earth on its axis is the cause of the apparent rotation of the celestial sphere and the bodies on it round the axis of the heavens.

The plane of the earth's equator extended to the heavens marks out the celestial equator, and is 90° distant from the celestial poles. The plane of the meridian of any place is a plane cutting the earth in a great

circle and passing through that place and through the north and south poles. If this plane is extended to the heavens it meets the celestial sphere and intersects in a circle called the *celestial meridian*. The celestial meridian passes through the celestial poles and the zenith of the place.

89. **The Horizon.**—Consider first the relation of an observer's horizon to the celestial sphere. Each place on the earth has its horizon, or rather three horizons, *i.e.* the term horizon is applied to three different circles or to their planes. A plane that touches a point on the surface of the sphere where the observer stands, and which extends out indefinitely on all sides to meet the celestial sphere, is a *horizontal plane*, or the plane of the horizon. Such a tangent plane is perpendicular to a plumb-line at that place, and the horizon that forms a tangent plane to the earth at any point is spoken of as the *sensible horizon*.

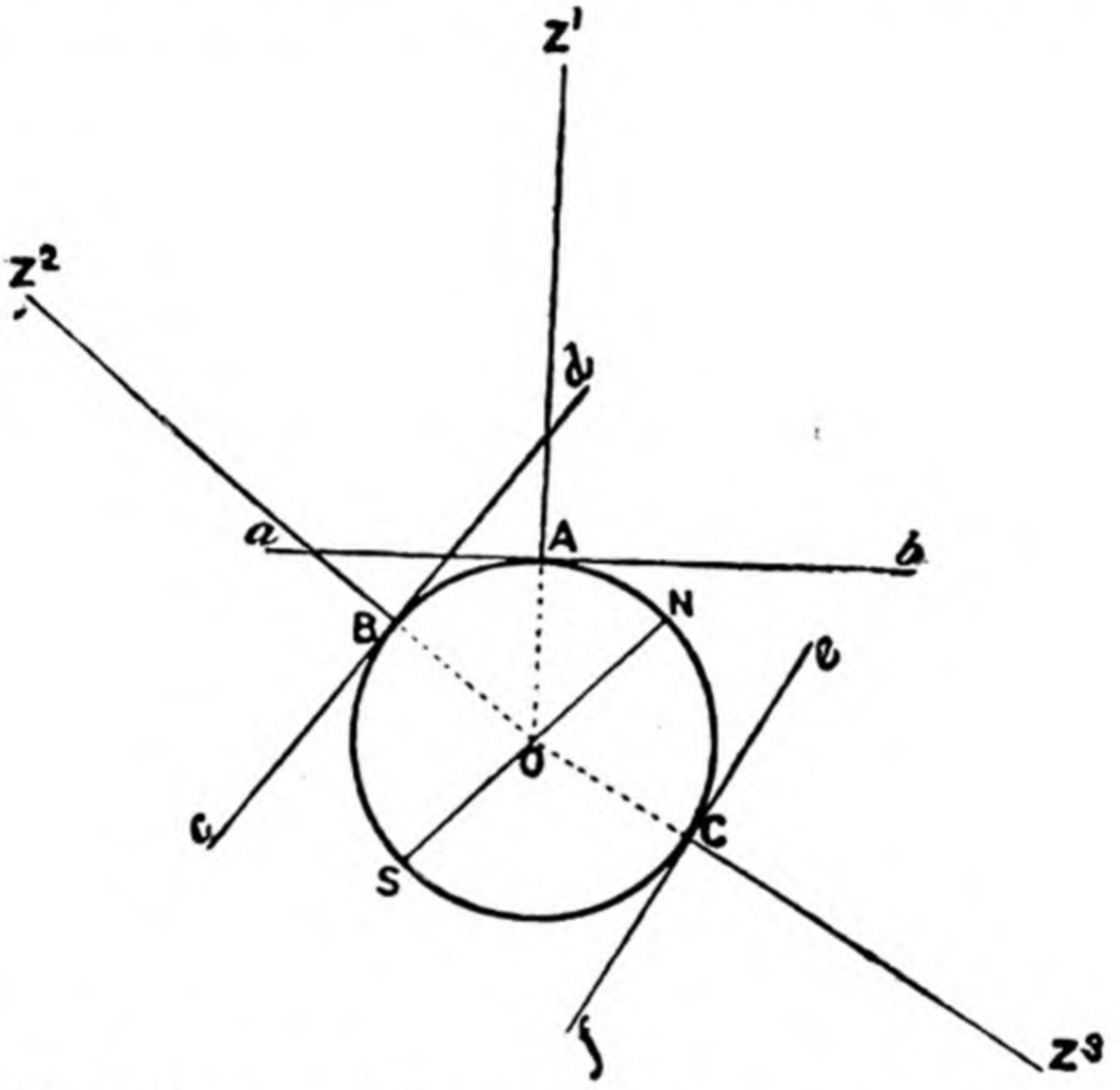


FIG. 98.—THE SENSIBLE HORIZON OF OBSERVERS AT A B AND C.
N S axis of earth, N being the North Pole and S the South Pole.

Our eye, however, is not at the surface of the earth, but at a certain elevation above. The actual circle that bounds our view, or the plane of this visible circle, is called the *visible horizon*. The higher an observer is the larger becomes the visible circle and the area of the earth that it includes. (*See* fig. 5 and Par. 1.)

Astronomers speak of another horizon for each place, called its *rational horizon*. This is a plane passing through the centre of the earth and parallel to the sensible horizon of a place (fig. 97, where a tangent plane at O would be the sensible horizon, the shaded plane below being the rational horizon). These parallel planes that form the horizons, sensible, visible, or rational of each place, on our earth merge into one on the vastly distant, immense celestial sphere, but it must be noted that the horizons of two different places may differ to any extent in *direction*, however small the globe may be in comparison to the celestial sphere.

At different places on the earth's surface, then, there thus are different horizons. Consider fig. 98. The circle represents a section of the earth. An observer at A will have a circular sensible horizon which is represented in section by the straight line *a b*. The vertical line perpendicular to this plane passes to A's zenith at Z^1. A line parallel to *a b* through the centre O would be the rational horizon of the observer at A, and the two parallel horizons would meet in the same circle on the infinitely distant celestial sphere surrounding the earth.

An observer at B will have a circular sensible horizon represented in section by *c d*, and his zenith will be at Z^2. The rational horizon would be parallel to this through the centre of the earth. A third observer at C will have a horizon represented in section by *e f*, and his zenith will be at Z^3. In other positions there would be other horizons and zenith points, and as each observer can see only what is above his horizon it is plain that the visible hemisphere varies with the position of the observer.

90. **Apparent Diurnal Motion of the Stars.**—At any place in the British Isles if we watch the stars on a clear night we soon notice that they change their position with respect to the horizon, owing to the earth's rotation on its axis. A star which rises at the east point of the horizon ascends in an arc to its highest point on the meridian in the south, and then declines and sets at the west point. A star that rises to the north of east passes upwards to its highest point in the south, reaching there a greater altitude than the first noticed, and then declines to set north of west. If we find a star that rises just at the north point, it can be noticed to rise higher and higher, to culminate on the meridian in the south, and then return to the north point without sinking below the horizon. Other stars in the north may be found moving round in circles that get smaller and smaller. These stars in fact move daily in circular paths round a star that hardly appears to move at all. This last star is the Pole Star, and is situated near one end of the axis of the heavens. The *altitude* of the Pole Star (its angular height above the horizon) is always equal to the latitude of the place of observation.

If we look south of east we shall find stars that move to their highest point in the south in arcs smaller than the star first noted that rose in the east. The stars, in fact, in consequence of the daily rotation of the earth, appear to move in circles of varying size round the celestial axis, but all move through their diurnal circles in the same time. Stars that have the whole of their diurnal circles above the horizon of an observer are called *circumpolar stars*. The stars, part of whose diurnal circle is above the horizon, complete the circles below the horizon. (In the daytime the path of a star when above the horizon can be observed in a telescope.) The same star at any one place always rises and sets at the same points, day after day and year after year. This is not the case with the sun, as we shall see later.

Fig. 99, which is drawn for the latitude of London, shows all the various kinds of diurnal star circles. It should be carefully examined and understood. The small circle at the centre may represent the earth on which the observer stands about 39° from the north pole, with the zenith at Z and the nadir at Z′. The axis of the earth prolonged meets the heavens at the celestial poles P P′—*i.e.* P P′ is the celestial axis round which the sky appears to turn. The great circle S Z P N Z′ passing through the zenith, the poles and the north and south points of the horizon is the observer's meridian circle. The great circle M E M′ W is the celestial equator, the plane of which is perpendicular

to the celestial axis and intersects the horizon at the east and west points. The rational horizon parallel to the sensible horizon at the

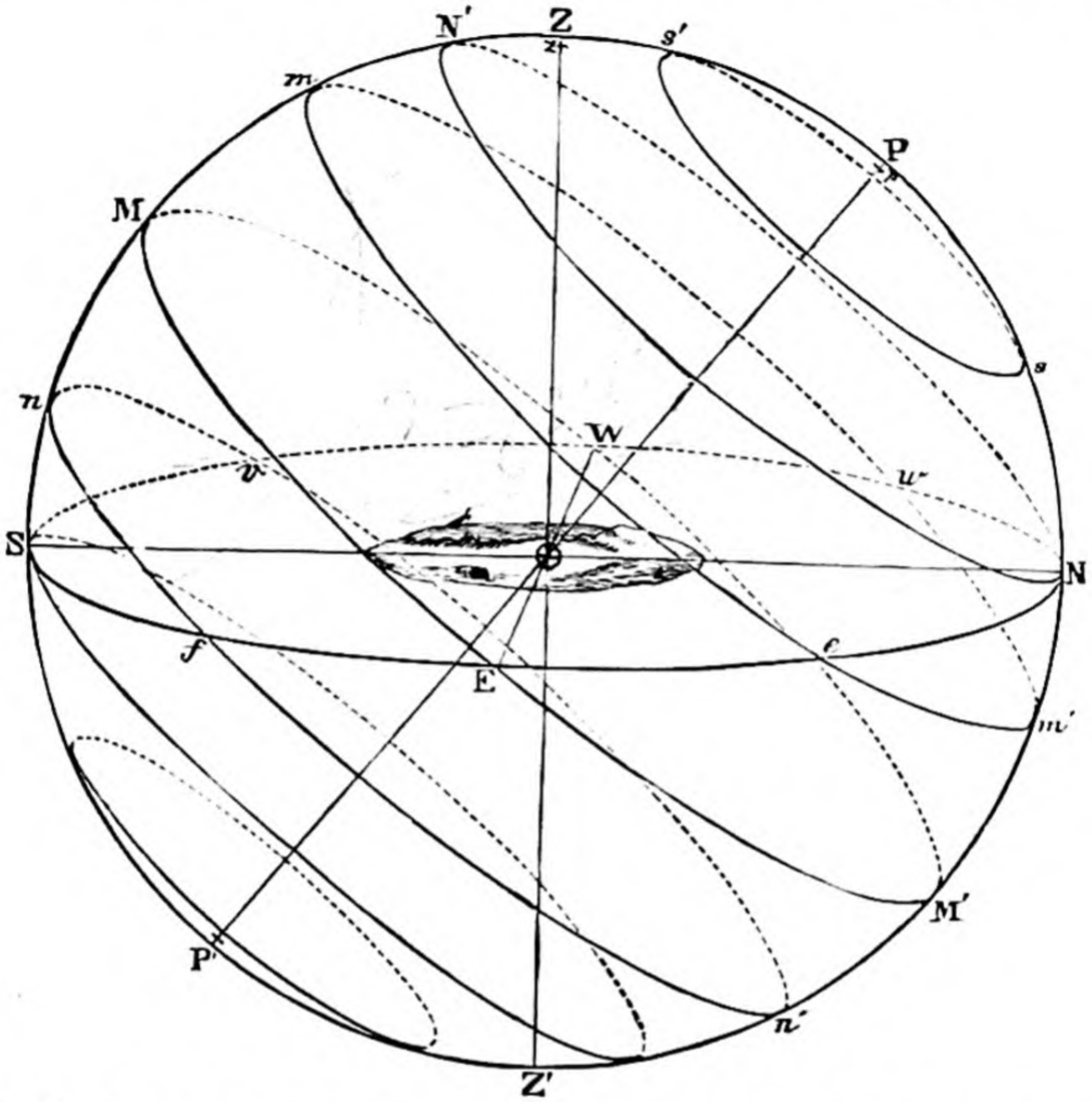


FIG. 99.—THE CELESTIAL SPHERE AND THE DIURNAL STAR CIRCLES IN THE LATITUDE OF LONDON. A star rising in the exact east at E passes to its culmination point on the meridian at M, and then sinks to set at W, half its diurnal circle being above the horizon and half below; a star rising at *e*, north of the east point, ascends to culminate at *m*, and then sinks to set at *w*, setting as far as the south of east as it rose north of east, being above the horizon more than twelve hours; a star rising in the north at N culminates at N′, and then descends to N, all its diurnal circle being above the horizon, so that it is a circumpolar star. Other stars, whose distances from the north celestial pole are less than the observer's latitude, are also circumpolar stars, and perform the whole of their diurnal circles, as *s s′* above the horizon. A star rising at *f*, south of the east point, culminates at *n* and sets at *v*, being less than twelve hours above the horizon. Stars rising at S, or stars nearer the south celestial pole, perform the whole of their diurnal circles below the horizon.

observer's position is represented by the great circle E S W N, the position of these letters indicating the cardinal points, east, south, west, north.

As an example of a constellation—*i.e.* a group of stars—that performs its daily circuit without ever setting to an observer in Britain, we will consider a part of the group called **Ursa Major,** or the **Great Bear.** Seven stars of this constellation are well known, and are called by various names — the *Plough*, *Charles's Wain*, the *Waggon*, the *Dipper*. Four stars of the Plough form a rough square, to one corner of which the other three stars, forming the handle of the Plough, are connected as a triangle. The two outermost stars of the square of the Plough are called the **Pointers,** because they lie very nearly on a line with Polaris, or the Pole Star. The distance of the Pole Star from the Pointers is about five times the distance of the Pointers from each other. The

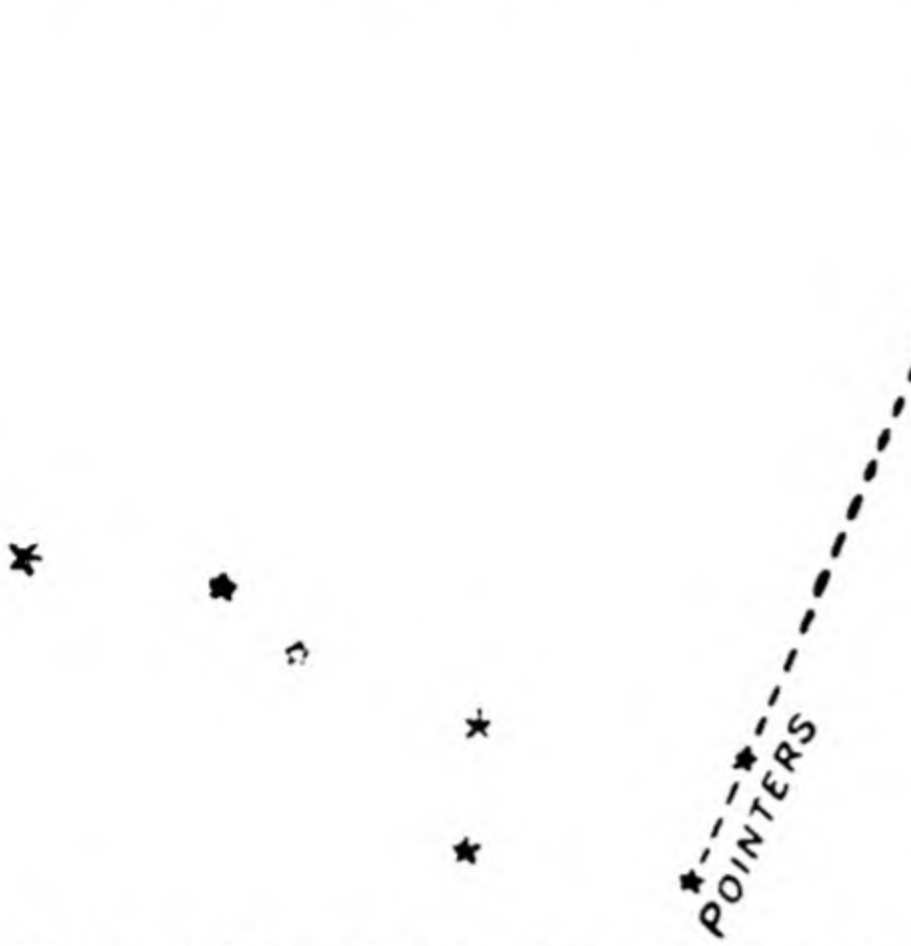


FIG. 100.—THE PLOUGH WHEN NEAREST THE HORIZON.

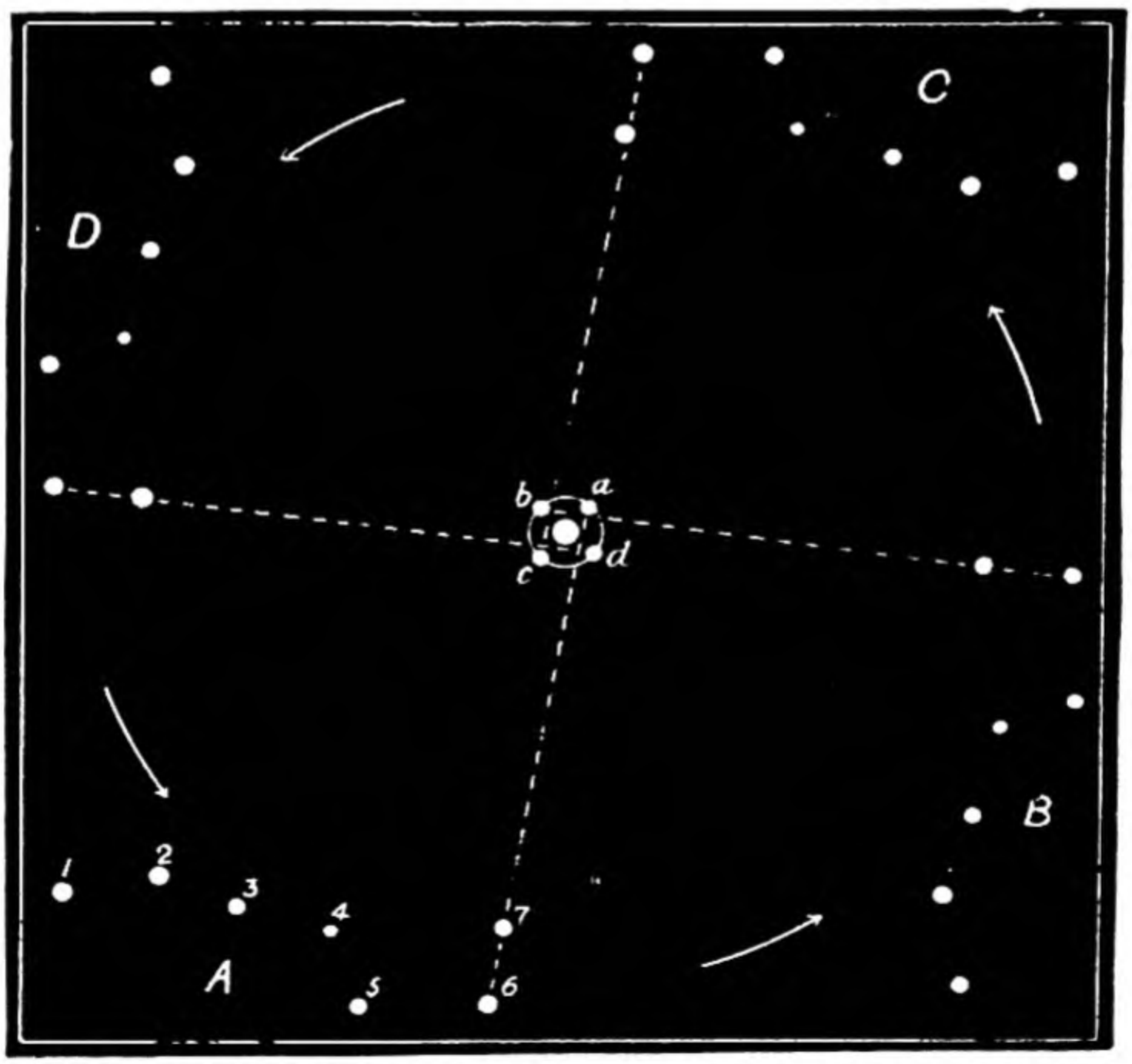


FIG. 101.—FOUR POSITIONS OF THE PLOUGH AND THE POLE STAR AT INTERVALS OF SIX HOURS—*a*, *b*, *c*, *d*, Four positions of the Pole Star as it rotates round the true Celestial Pole.

Pole Star is so called because it lies near the north pole of the celestial sphere—the point round which the other stars seem to rotate. The

Pole Star is easily recognised by the help of the Pointers, as it is much brighter than any other star near it.

The seven stars forming the Plough rotate daily round the celestial pole, keeping the same position in relation to each other, and never setting to an observer in the British Isles. At one time the Plough is seen below the pole of the heavens near the horizon, the group having the form seen in fig. 100 ; at another time the Plough is seen inverted, high in the heavens near the zenith. On another occasion the Plough may be found to the right of the Pole Star, and again may be seen on the left. Any intermediate position may also be observed, for the stars of the Plough move daily in circuits round the celestial pole, and with the help of a telescope their whole course can be followed. Even without a telescope a watch of some hours will show a portion of the course and impress the reader better than any description. The Pole Star itself describes a small circle round the true pole of the heavens, its daily path being like that of the Plough in a circular course.

91. **The Daily Movements of the Stars at Different Latitudes.**—In the previous paragraph we have described the diurnal path of the stars to an observer in the northern hemisphere, somewhere near middle latitude, say at London, and have seen that the stars appear to rotate daily round the celestial sphere in circles that are here oblique to the observer's horizon, but parallel to the celestial equator. As an observer goes northward the altitude of the pole increases by just as many degrees as the observer's latitude increases, and the celestial axis therefore forms a larger angle with the plane of the horizon. Let the observer pass from London, say to Edinburgh. Here also he has a new horizon, zenith, and sphere of observation, and the new horizon is differently inclined to the axis about which the heavens appear to rotate. The diurnal circles of the stars are now less oblique and more parallel to the horizon, for they always appear to rotate in planes perpendicular to the celestial axis. At the north pole itself the rational horizon parallel to the tangent plane at the pole of the earth will be the plane of the celestial equator, and the celestial pole will be the zenith. The stars always revolve in parallel circles round the celestial axis, and as the planes of these circles are perpendicular to this axis the diurnal circles of the stars seen at the poles will be circles parallel to the plane of the horizon, which here is the same as the plane of the celestial equator (refer to fig. 97) ; and suppose a tangent plane at the earth's north pole and a rational horizon through the centre of the earth parallel to this tangent plane. Hence the diurnal star-paths at the poles are as represented in fig. 101, and only one-half the stars are here seen at all. Those below the celestial equator are never seen. Only one star circle is shown above and below the horizon ; others may be put in by the reader.

If the observer pass from London southwards the altitude of the pole star diminishes, the celestial axis makes a smaller angle with the observer's horizon, and the diurnal circles of the stars become more and more inclined to the horizon. At the equator itself the two poles of the heavens are on the horizon ; the celestial axis itself passes through the horizon (fig. 103). The zenith is on the celestial equator, which of course is perpendicular to the earth's axis that passes in the figure from N to S. The heavens still appearing to revolve about the celestial axis, the stars are seen to rise on all parts of the eastern horizon, and still describing circles parallel to the equator, set on the west of the horizon. Every star on the celestial sphere rises at some part of the

day, and sets twelve hours later, describing half its journey in a semicircle above the horizon, and half its journey below. The greatest semicircle is described by stars situated on the equator, and the semicircles, though all described in the same time, get smaller and smaller the farther north or south of the equator the star is. It is thus clear that at the equator all stars rise and set, and that in one complete day the whole celestial sphere has been visible.

We now see that the appearances at different latitudes on the earth's surface are explained by the varying inclination of the observer's horizon to the axis of rotation of the celestial sphere as the place of observation is changed. (*See* fig. 98.)

We may sum the matter up thus :—

1. To an observer at one of the poles of the earth (say the north pole) the north celestial pole is at his zenith and the opposite celestial pole is at his nadir. The plane of the celestial equator is the plane of his horizon. The stars seen are all circumpolar stars, and describe circles parallel to his horizon, never rising nor setting while the same half of the heavens is continuously visible. The stars in the other half of the heavens describe parallel circles below his horizon, but are never seen.

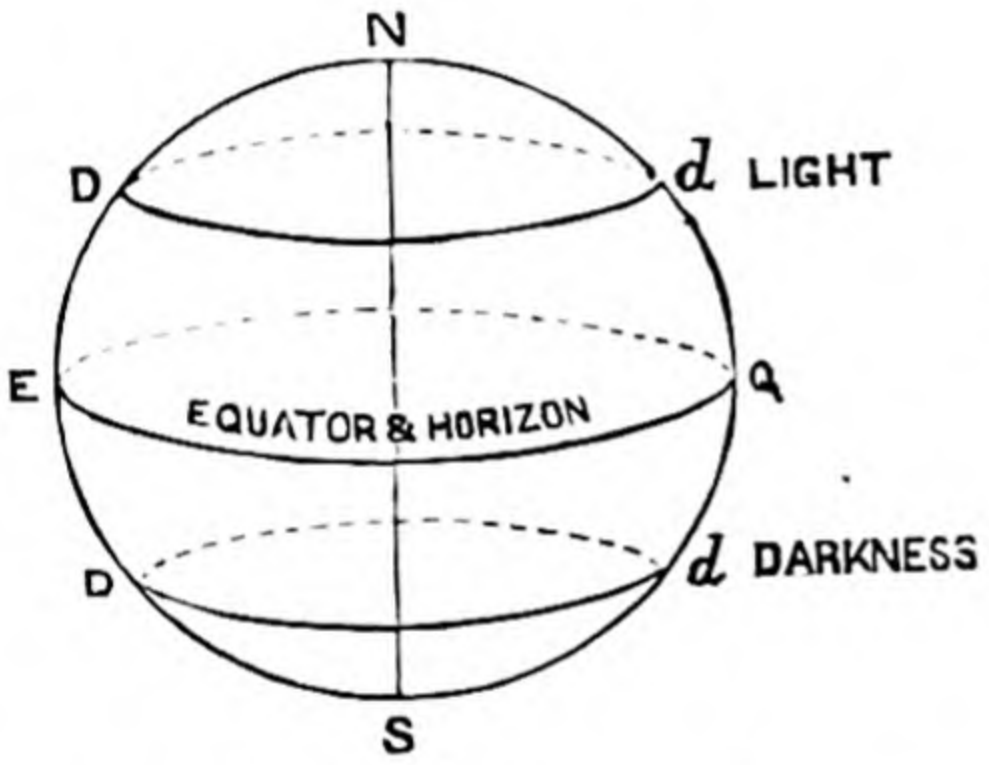


FIG. 102.—PARALLEL SPHERE, WITH POLE AT ZENITH, AND CELESTIAL EQUATOR FOR HORIZON.

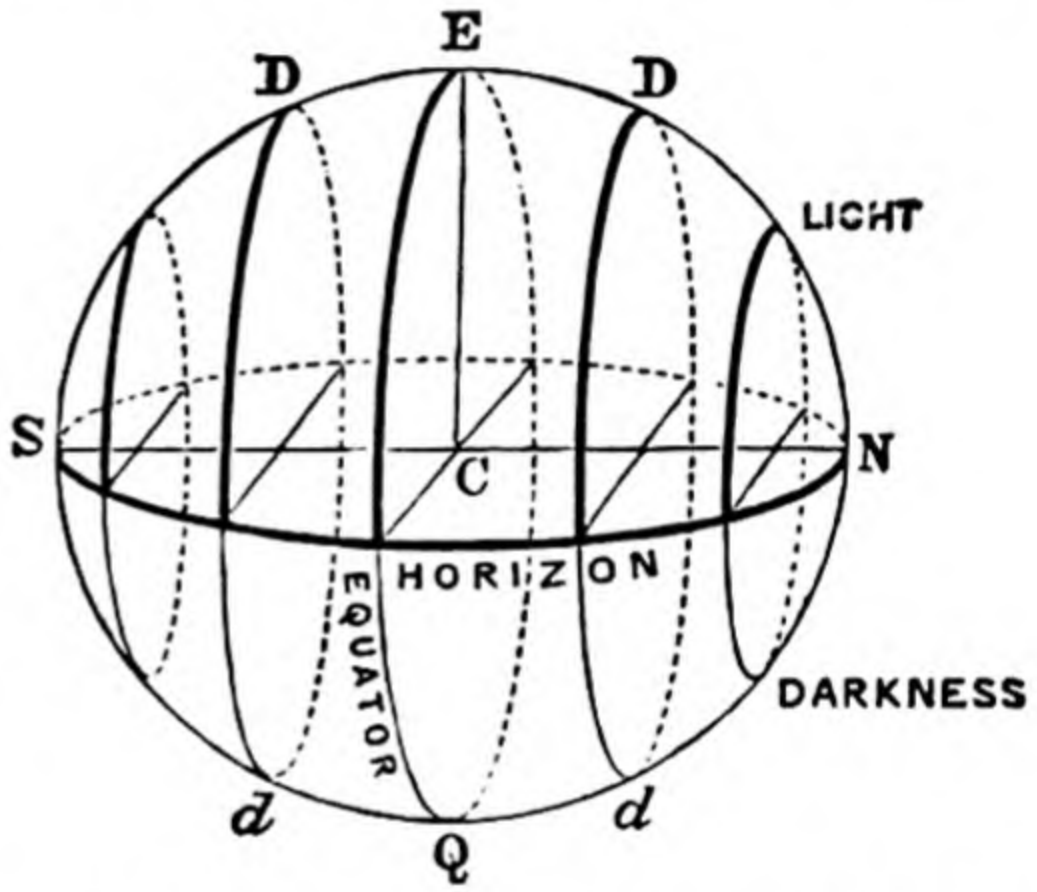


FIG. 103.—RIGHT SPHERE: POLES ON HORIZON. N S, CELESTIAL AXIS.

2. To an observer at the equator the two celestial poles are on the horizon. All stars rise and set in circles perpendicular to the horizon, so that in one complete day the whole sky with its stars becomes visible.

3. At any place between the poles and the equator the altitude of the visible pole is equal to the latitude of the observer, and the diurnal circles of the stars are more or less oblique to the horizon. He sees circumpolar stars that perform their daily apparent motion above the horizon without setting, and stars which rise and set. Below the horizon are stars that never rise, and which therefore the observer never sees.

From what we have said the reader should be able to draw a diagram of the celestial sphere at any latitude, and put in the diurnal star circles of any stars.

In drawing a diagram of the celestial sphere to show the diurnal star circles, first draw a complete circle to represent the observer's meridian, as indicated in Par. 88. Then draw an ellipse across to show the horizon of the observer as seen obliquely from above, marking the centre O as the observer's position. Put in a point on the meridian vertically above to represent the observer's zenith Z. Next mark the pole at a height above the north point of the horizon equal to the observer's latitude. Now put in the celestial equator EQ as an ellipse meeting the meridian in two places, each 90° from the pole, and cutting the horizon at the east and west points *EW*. This will serve as the skeleton sphere. A little geometry will enable the reader to put in the number of degrees between the pole and the zenith, between the pole and the highest point of the celestial equator on the meridian, between the meridian height of the equator and the south point of the horizon, and between the south point of the horizon and the south celestial pole. Any diurnal star circles may then be added, all being kept parallel to the celestial equator so that the planes of the circles are perpendicular to the celestial axis. Fig. 104 is a diagram of the celestial sphere for an observer at lat. 30° N. Put in diurnal circles for stars with declinations of 30° N., 45° and 60° S. (Angular distance from the celestial equator measured on a celestial meridian is called **declination,** and is north or south according as the body is north or south of the celestial equator. The **polar distance** of a heavenly body is the angular distance of the body from the celestial pole measured on a meridian or arc of a great circle passing from the pole through the body.)

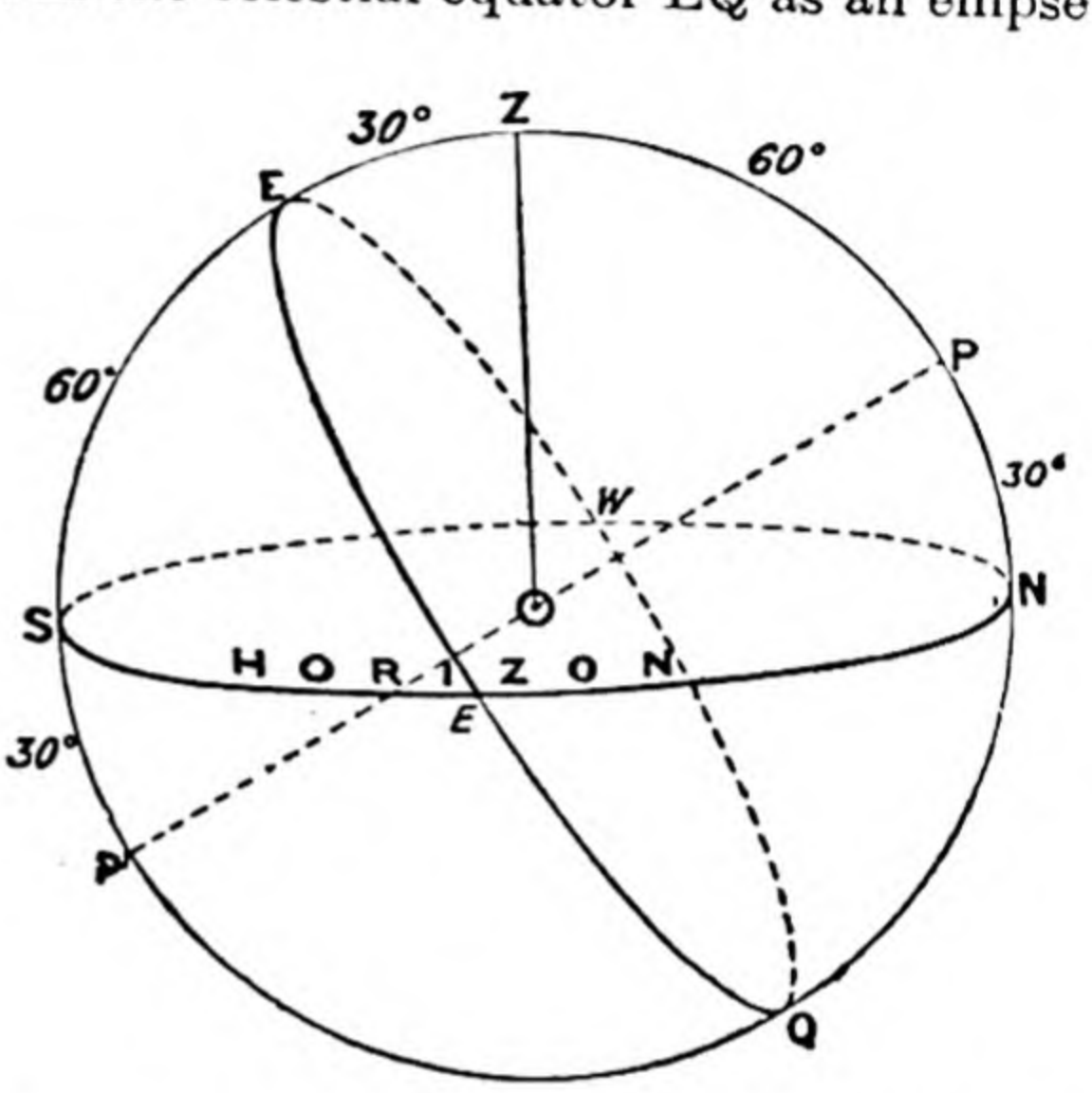


FIG. 104.—THE CELESTIAL SPHERE AT LAT. 30° N. (diurnal star circles may be put in).

92. **Sun's Daily Apparent Motions on the Celestial Sphere during a Year.**—In the daytime the sun is usually the only object to be seen above the horizon, for its bright light overpowers the light from the stars and other heavenly bodies. We soon notice that he has a daily motion across the sky of the same nature as the motion of the stars. Every clear day in Britain he is seen to rise in the east, move in an arc across the heavens so as to reach his highest point at noon in the exact south, then to decline until he sets in the west. The phrases 'in the east' and 'in the west' are here used, as in common speech, to include any part of the horizon near the east and west points. For a careful observer will soon perceive that

the sun does not, like a fixed star, rise and set at the same place on the horizon throughout the year, although he describes his circular path in a plane perpendicular to the axis of the heavens, reaches his highest point in the exact south at noon on every day, and is in the north below the horizon at midnight. Hence the sun does not describe the same arc each day in the sky as a star does.

On March 21 the sun rises exactly in the east, culminates on the meridian at noon, and sets exactly in the west. His path on this date is on the celestial equator and day and night are equal in all parts of the world, this date being Spring Equinox. After March 21 it rises more and more north of east and sets more and more north of west, the magnitude of his daily arc above the horizon increasing until June 22, the date of the Summer Solstice. After June 22, on which day the sun describes his greater arc above our horizon, the visible

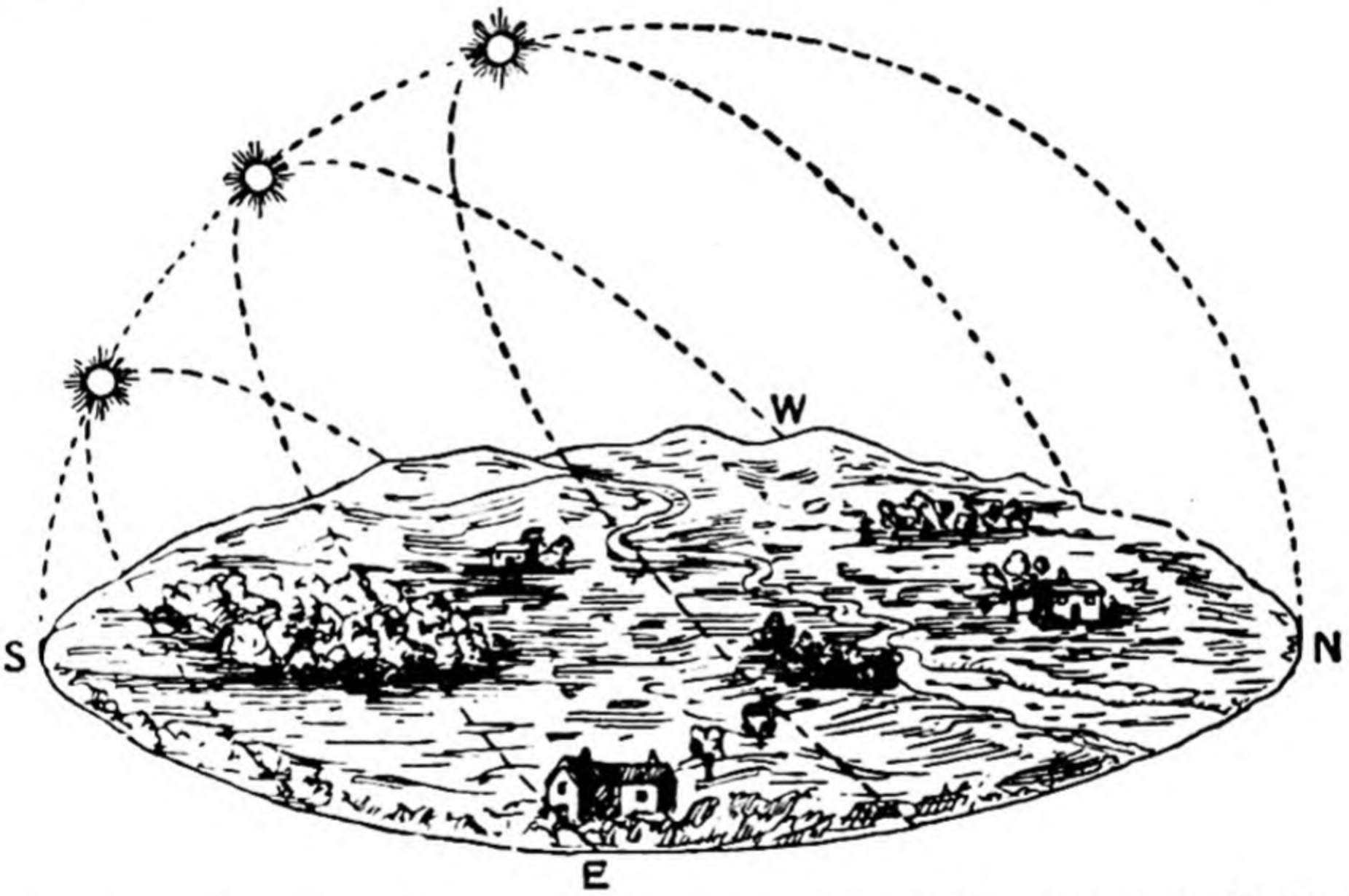


FIG. 105.—THE SUN'S DAILY PATH IN THE SKY, AND ITS NOONDAY ALTITUDE ON THE MERIDIAN, at different parts of the year—at midwinter, at the spring or autumn equinox, and at midsummer. The paths for the intermediate days lie between those shown. About lat. 60° N.

part of his daily diurnal circle decreases until the rising point again reaches the east on September 22, the date of the Autumnal Equinox. After September 22 the rising point of the sun is south of east and the setting point south of west, with a daily diminishing arc and time above the horizon until December 22. On this date the part of the sun's arc above the horizon is smallest and the length of day shortest. It is the date of the Winter Solstice. After December 22 the rising point begins to move back again towards the east, the daily arc above the horizon to increase, and the time of daylight to lengthen. On March 21 his path is again on the celestial equator.

Fig. 105 shows these daily paths to an observer at London. Put them on fig. 99 to show the part of the sun's daily path below the horizon, remembering that it does not get more than 23½° N. of E M W M′ nor more than 23½° S. Figures may also be drawn for other latitudes. The different apparent daily paths of the sun in the sky are due to the fact that in consequence of the yearly revolution of the earth round the sun with its axis inclined 23½° from the perpendicular to the plane of its orbit, the sun appears to move each year round a great circle of the heavens called the ecliptic. The ecliptic cuts the celestial equator at two opposite points at an angle of 23½° (the obliquity of the ecliptic) so that one half the ecliptic is above the equator and one half below.

Hence one half of the apparent daily motion of the sun is during the year above the celestial equator, and one half below. Angular distance from the equator is called **declination** and is reckoned north or south according as the body is north or south of the equator. We say, therefore, that the sun's declination increases from 0° when on the equator on March 21 to 23½° N. It then diminishes, for the sun slowly returns to the equator on September 22, when it is again 0°. From September 22 the declination is south and increases to 23½° S. on December 22. There is thus a total difference of 47°.[1] (*See* Questions 176, 177, 178.)

From what has been said about the appearance of the diurnal arcs of the stars at different latitudes, it will be understood that at the poles where the celestial equator and the horizon are the same, the various diurnal arcs of the sun are parallel to the horizon, whether it be on the equator at the equinoxes, above the equator till June 21, or below the equator after September 22. At the equator the diurnal paths of the sun are perpendicular to the horizon, whatever be its declination. (Compare figs. 102 and 103, and put on these figures the apparent path of the sun at the equinoxes and solstices.) We can therefore say that the changing positions of the sun on the ecliptic with its varying declination are the cause of the variation in the altitude of the noon-day sun, the variation of the length of day and night, the resulting

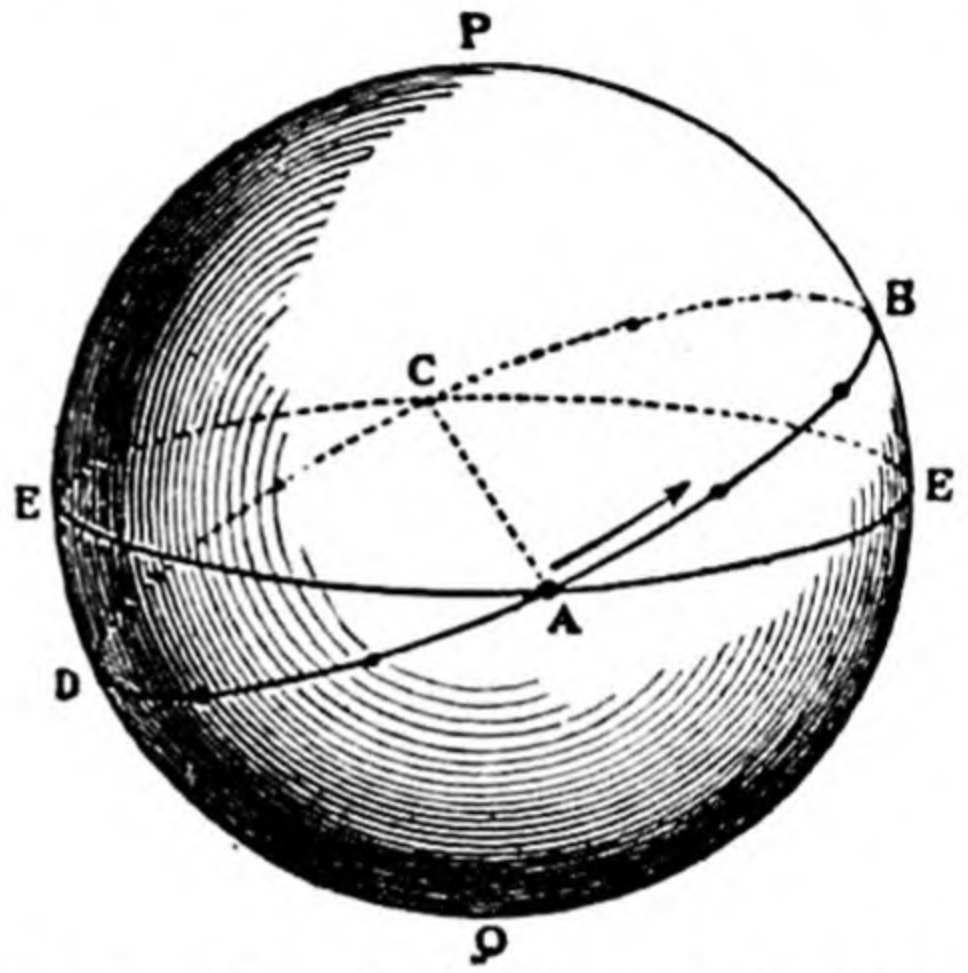


Fig. 106.—Diagram of the Celestial Sphere, showing the Celestial Equator EE intersected by the Ecliptic DB at the Nodes A and C. A is the vernal equinox, C the autumnal equinox, B the summer solstice, and D the winter solstice. The arrow shows the direction of the sun's apparent annual motion on the ecliptic. The angle BAE is the obliquity of the ecliptic. The varying declination of the sun as it moves on the ecliptic is evident.

[1] The changes on the sun's declination do not always take place at the same rate. They can, however, be accurately found for each day in the year, and are set out in the Nautical Almanack, or Whitaker's Almanack.

phenomena of the seasons. But it may be said we ought not to explain the varying length of the day and night, and the seasons by the **apparent** motions of the sun on the celestial sphere, since these events are really due to the revolution of the earth round the sun and the constant inclination of the earth's axis (Par. 6). Since the motion of the two bodies, however, is relative motion either way of explanation is useful.

Refer again to Par. 6 to understand the varying height of the sun on the celestial sphere, and to see that the whole phenomena of the seasons arise from the fact that the inclination of the earth's axis causes this body to be differently inclined towards the sun at different parts of its orbit. Fig. 107 shows this clearly for the summer and winter solstices when the declination of the sun is $23\frac{1}{2}°$ N. and $23\frac{1}{2}°$ S. respectively.

As shown in the figure, the sun is vertical over the Tropic of Cancer, $23\frac{1}{2}°$ N. of the equator, on the first date, and over the Tropic of Capricorn, $23\frac{1}{2}°$ S. of the equator, on the second date. At London then

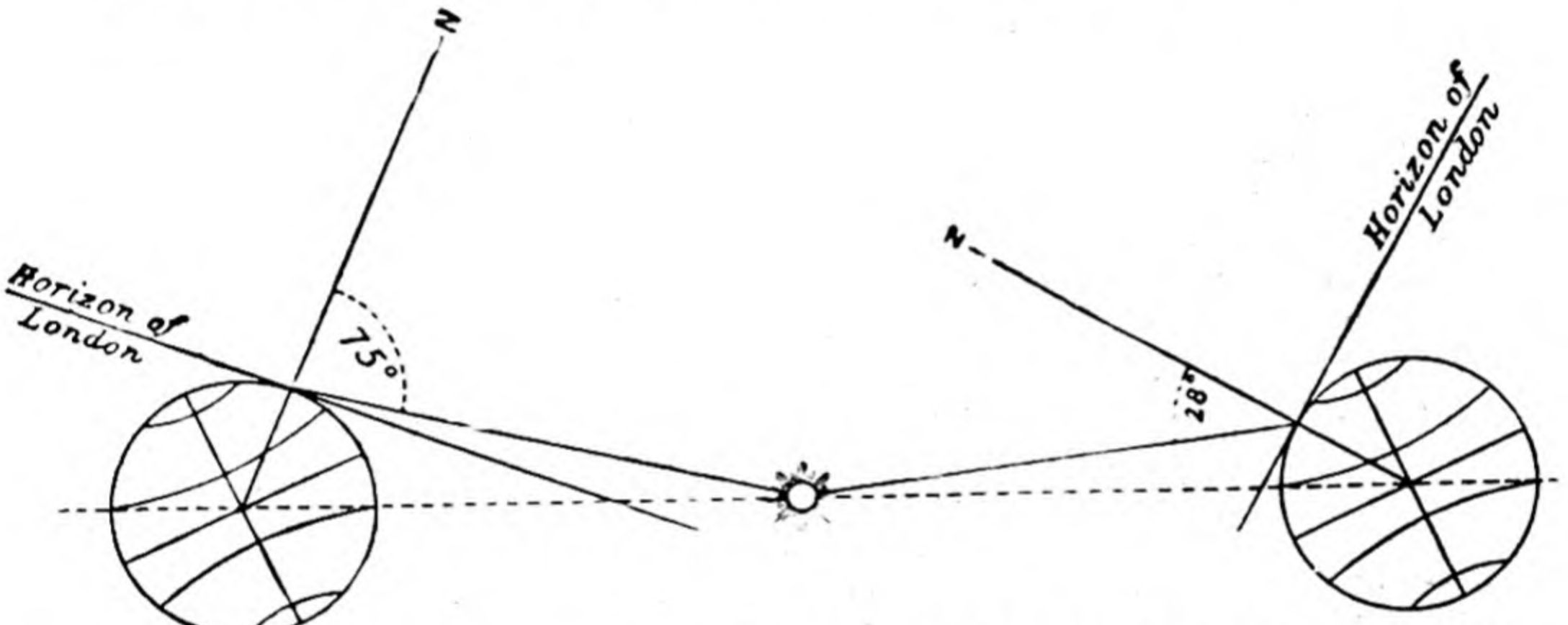


FIG. 107.—DIAGRAMS SHOWING THAT THE DIFFERENT MID-DAY ALTITUDES OF THE SUN IN JUNE AND DECEMBER AT LONDON ARE DUE TO THE OPPOSITE POSITIONS OF THE EARTH IN ITS ORBIT AND TO THE PARALLELISM OF ITS AXIS IN THESE POSITIONS.

$51\frac{1}{2}°$ N. lat., the noon-day distance of the sun from the zenith on June 21 is 28° ($51\frac{1}{2}° - 23\frac{1}{2}° = 28°$), and its noon-day altitude above the horizon is therefore 62° ($90° - 28° = 62°$). On December 22, when it is vertical $23\frac{1}{2}°$ S. of the equator, its noonday altitude is 47° less, *i.e.* its altitude is 15°, and its zenith distance 75°; or thus, for December 22:—the sun is $23\frac{1}{2}°$ S. of the equator, so that it is $23\frac{1}{2}° + 51\frac{1}{2}° = 75°$ from the zenith of London, with an altitude, therefore, of $90° - 75° = 15°$. In the same way the distance of the sun from the zenith and its noon-day altitude can be found at any time and place, if we know the latitude of the place and the angular distance of the sun from the equator. This latter distance is called the **declination** of the sun. As an exercise the pupil may find the noon-day altitude of the sun at one of the equinoxes, and when its declination is 10° S. (*a*) at London, (*b*) at Sydney, lat. 33° 54′ S.

93. **Apparent Yearly Revolution of the Sun through the Stars on the Celestial Sphere.**—We have seen how the daily **rotation** of the earth on its axis causes a daily rotation of the star sphere, and how the sun's daily motions on the celestial sphere are explained. Now, the earth has besides its daily rotation a motion round the sun called its **revolu-**

tion, making a complete circuit or orbit round the sun in 365¼ days. This yearly revolution of the earth causes the sun to have an **apparent yearly** motion eastward round the heavens in the great circle called the

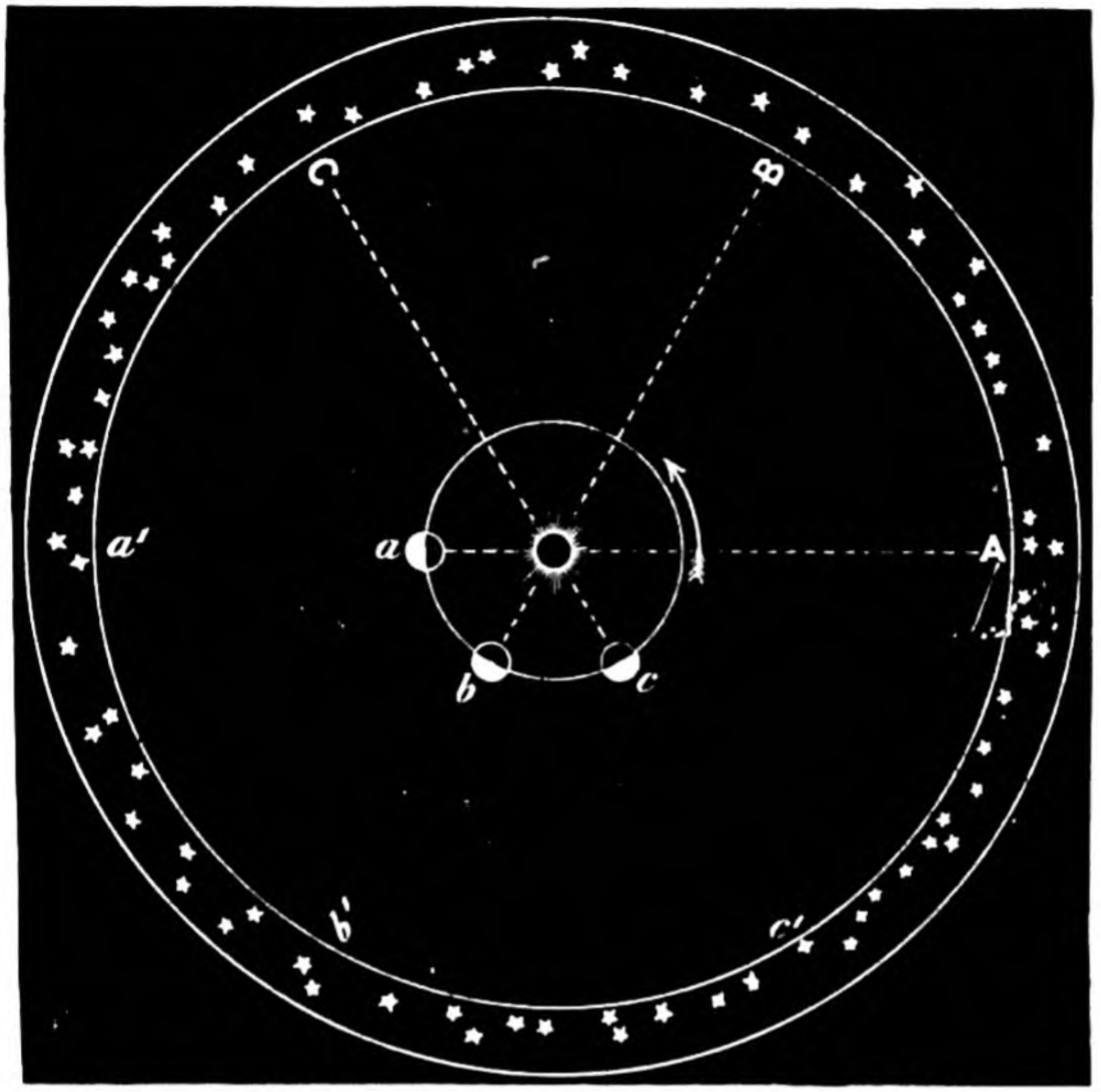


FIG. 108.—ILLUSTRATING THE APPARENT YEARLY MOTION OF THE SUN THROUGH A CIRCLE OF THE STARS, owing to the real yearly revolution of the earth round the sun, and why different stars are seen in the same part of the sky at the same hour of the night during different parts of the year. The inner circle shows us a plan of the earth's orbit round the sun, *a*, *b*, and *c* being three positions of the earth in its orbit at intervals of about two months, the sun occupying the centre. When the earth is at *a*, the sun appears to an observer to be among the stars at A. At midnight he sees the stars in the opposite part of the sky at *a'*. When the earth has moved to *b* the sun appears to be among the stars at B, and the midnight stars seen are at *b'*. In a year the sun appears to make a complete circuit of the stars. The two outer circles may represent the belt of the zodiac, which could be divided into twelve equal parts to represent the signs of the zodiac. The sun enters the sign Cancer on June 22; a month later it reaches Leo, and so on.

ecliptic. How shall we observe or detect this apparent eastward motion of the sun? If we look out at the same hour of the night, but at different times of the year, we shall find that the same stars are not visible in the same positions. We shall see this more clearly if we fix

on any one star and watch for its appearance on successive nights. Each succeeding night it rises four minutes sooner and sets four minutes sooner than it did the night before. Thus, if in spring at nine o'clock it is just rising, it will be high up in the heavens at the same hour in summer, and in autumn it will be setting at the same hour. During the winter months it will be below the horizon at this hour, and we should have to wait some time for it to rise. As spring comes on again, it will rise earlier and earlier till on the same day of the month as we first began observing it it will rise at nine o'clock. So it is with all the stars. The apparent yearly eastward motion of the sun round the heavens due to the yearly revolution of the earth round the sun thus causes the stars to seem to pass westward behind the sun, so that the stars on each successive night appear to be slightly to the westward of the position they occupied at the same hour on the previous night. Thus stars rise earlier and set earlier on successive nights, the amount, viz., four minutes, being such that in a year's time they come back to the same positions at the same hours, for 365 times four minutes make up one day nearly.

The apparent yearly path of the sun through the stars of the celestial sphere is on the great circle called the ecliptic. A belt of the heavens 16° wide and 8° on each side of the ecliptic is called the **zodiac,** *i.e.* the ecliptic runs through the middle of the zodiac. The circular belt called the zodiac is divided into twelve equal arcs or parts termed the **signs of the zodiac.** The sun thus appears to move through the signs of the zodiac. The names of the twelve signs of the zodiac in Latin and English are as follows:—1. **Aries,** the ram; 2. **Taurus,** the bull; 3. **Gemini,** the twins; 4. **Cancer,** the crab; 5. **Leo,** the lion; 6. **Virgo,** the virgin; 7. **Libra,** the balance; 8. **Scorpio,** the scorpion; 9. **Sagittarius,** the archer; 10. **Capricornus,** the goat; 11. **Aquarius,** the water-bearer; 12. **Pisces,** the fishes. The stars are arranged in groups called **constellations.** In all their apparent movements they keep the same relative positions with respect to one another, and are therefore called **fixed stars.** A few bright objects like stars while partaking of the daily motion from east to west change their positions with respect to the fixed stars and one another. These are the **planets,** and, like the earth, are members of the Solar System (*see* Glossary).

CHAPTER XIII

THE MOON AND ITS PHASES

94. **The Moon.**—The moon is a satellite of the earth, and revolves round it while the earth is revolving round the sun. Its mean distance from the earth is 238,000 miles, while the sun's mean distance is 92,500,000 miles. Though apparently as large as the sun, owing to its nearness, the moon's real diameter is only 2,160 miles.

Besides a daily apparent motion from east to west, due to the daily rotation of the earth, it is easy to notice that the moon has an opposite motion eastward among the fixed stars.

Observe the moon any clear night and note any bright stars near it on the west. In a few hours the moon will be seen farther to the east of the stars. On the following night it will be 13° to the east. In consequence of its eastward motion it rises about fifty minutes later each night.

A complete revolution of the moon round the heavens from one fixed star to the same fixed star is called a **sidereal** revolution, and occupies about $27\frac{1}{3}$ days. The moon requires a longer time to go through a revolution with respect to the sun, as the sun also moves eastward among the stars, though at a slower rate. Hence the **synodic** month, or the time occupied by the moon in passing from the sun round to the sun again, is longer than the **sidereal** month by more than two days. The mean value of the synodic month is 29·53 days, and this is the ordinary **lunar** month. **Calendar** months consist of a whole number of days —28, 30, or 31, as the case may be. In a year there are twelve calendar months, but thirteen lunar months.

The moon's path among the stars is not situated in the same plane as the earth's path round the sun, for the moon's orbit is found to be inclined to the plane of the ecliptic at an angle of about 5°. The points at which the moon's orbit cuts the plane of the ecliptic are called the moon's **nodes.** There is an ascending node and a descending node (*see* fig. 109).

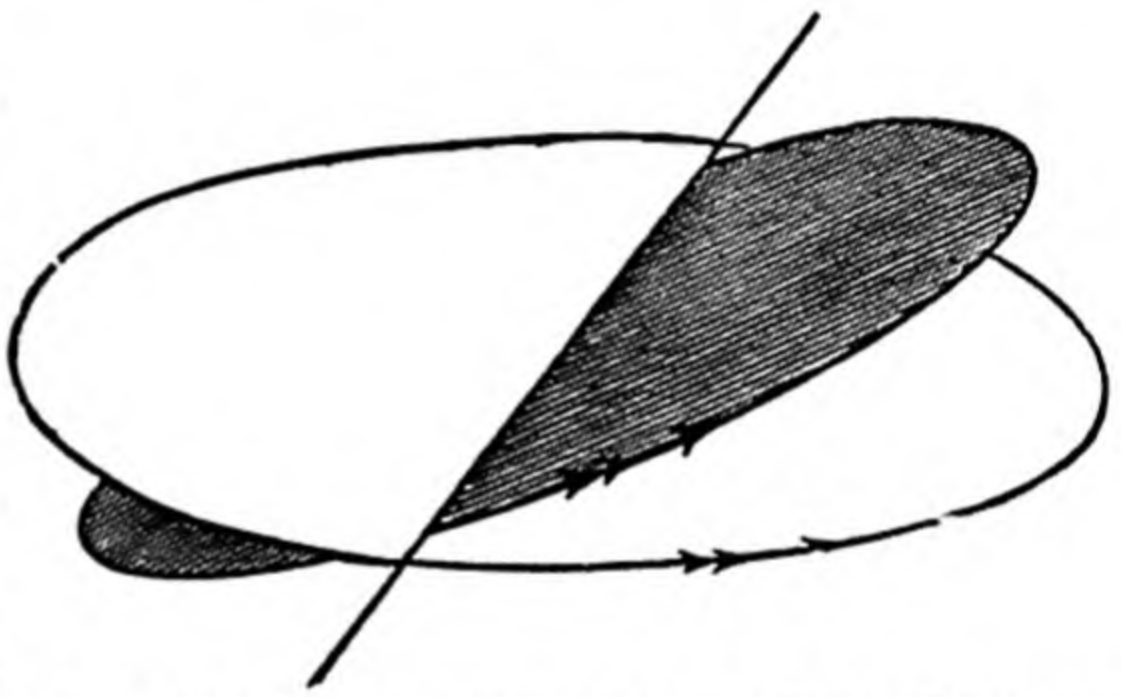


FIG. 109.—THE PLANES OF TWO ORBITS INTERSECTING ONE ANOTHER AT THE LINE OF NODES.

When the moon in its orbit lies between the sun and the earth it is said to be in **conjunction** with the sun; when the earth is between the moon and the sun, 180° from the sun, the moon is said to be in **opposition** to the sun. At either of the two points midway from conjunction and opposition—*i.e.* 90° from conjunction or opposition—the moon is said to be in **quadrature.**

The moon is an opaque, cold globe, covered with mountains, extinct volcanoes, and plains. It has neither water nor atmosphere, and always presents the same surface to the earth, in consequence of rotating on its axis in the same time as it revolves round the earth. Moon-light is only reflected sunlight, the illuminated hemisphere being always turned towards the sun. When we see the whole lit-up side of the moon, it appears circular, and we say the moon is full. But we cannot see the whole of the illuminated hemisphere from the earth at all times. The various shapes this illuminated hemisphere assumes in the course of its journey round the earth are called the **phases** of the moon.

95. **Phases of the Moon.**—The diagram (fig. 110) shows the relative positions of the earth, moon, and sun at eight different positions of the moon in its orbit round the earth. It also shows how the phases of the moon are accounted for on the assumption, which is true, that the moon is an opaque body illuminated by the sun. The sun is at an immense

distance to the right, and its rays reach the moon and earth in parallel lines.

At A, when the moon is between the earth and the sun, it is in **conjunction,** and no portion of the hemisphere illuminated by the sun is visible. It is then said to be **new moon.** This is denoted in almanacs by the symbol (●).

At B, about three or four days afterwards, a small part of the illuminated hemisphere is visible on the earth, and this appears as a thin crescent in the west of the sky to the east of the sun that has just set.

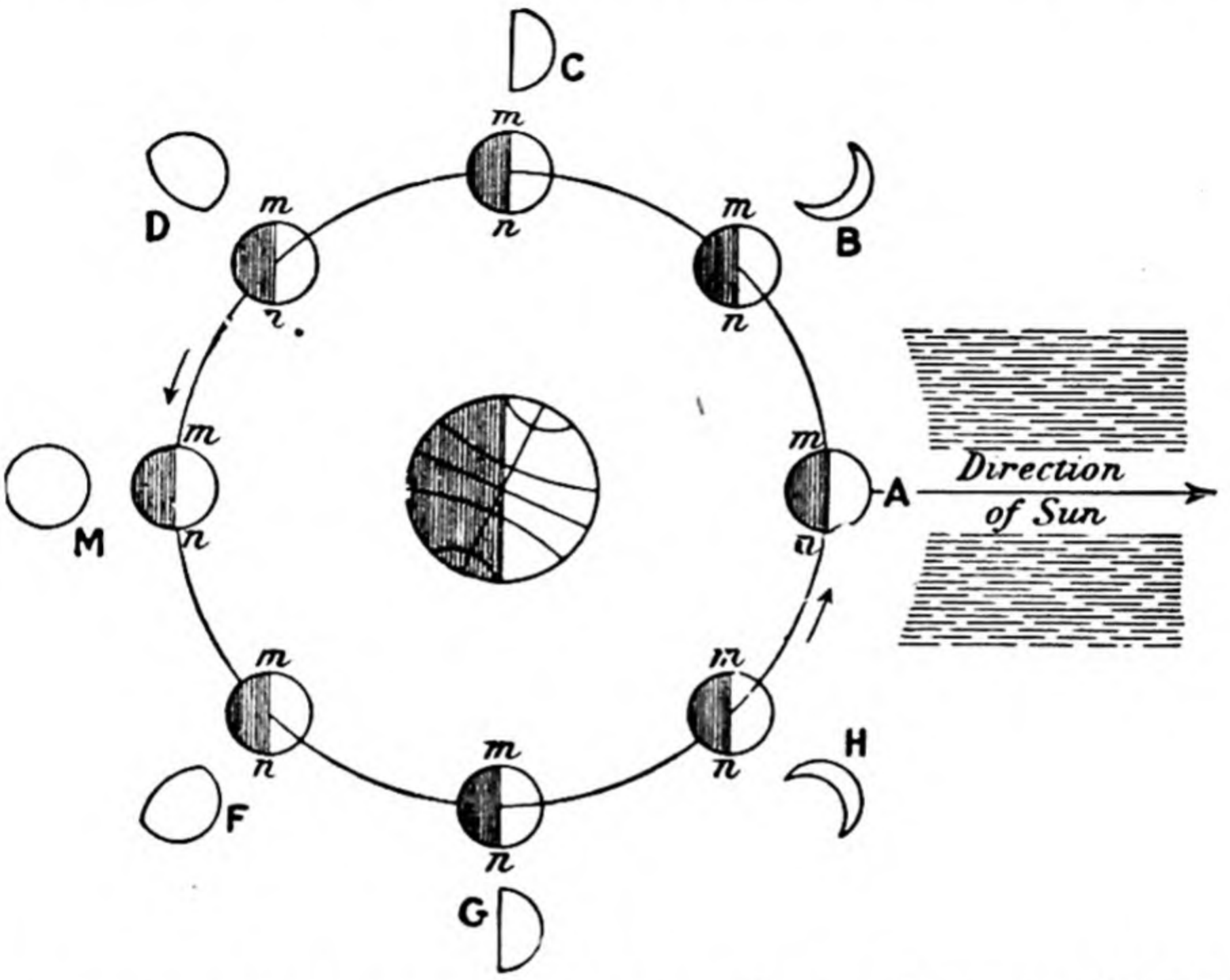


FIG. 110.—THE PHASES OF THE MOON. The sun is supposed to be at a great distance on the right—a distance of about 390 times the distance of the earth from the moon. Line *m n* perpendicular to direction of distant sun and separating illuminated half of moon from unilluminated half. The outside figures show the different phases.

The points of the crescent moon are called **cusps,** or **horns.** The horns of this crescent are turned towards the east, as the illuminated portion is towards that part of the celestial sphere in which the sun is then situated in the west below the horizon. The dark part of the hemisphere of the moon that is turned towards the earth is therefore on the east or left side of the moon at this period. In popular language the moon is spoken of as 'new' when it is thus seen as a thin crescent in the west in the evening; but true 'new moon,' as just stated, is the moon in conjunction with the sun, and is invisible. As the days go on the moon gets farther from the line joining the sun and the earth, and more and more light reaches the side turned towards the earth. The illuminated surface that is visible increases, so that the crescent becomes thicker and thicker, and the line separating the illuminated

part from the non-illuminated part less and less curved. The moon is said to be *waxing*.

At C the moon's angular distance from the sun, called by astronomers its **elongation,** is 90°, and it is said to be in **quadrature,** or at the **first quarter** (☽) of its revolution. Here one-half the lit-up hemisphere is seen by the observer on the earth, and the moon appears as a bright semicircle popularly called 'half-moon,' the terminator or dividing line between the illuminated and unilluminated part being a straight line.

At D more than half the lit-up hemisphere is seen from the earth, so that the enlightened visible surface appears greater than a semicircle and less than a circle. The moon is then said to be *gibbous* (Lat. *gibbus*, a 'hump').

In about fourteen days after new moon, our satellite is nearly in a line with the earth and the sun; the earth being in the middle, it is in **opposition** to the sun, as at M. The whole of the illuminated hemisphere can be seen by an observer on the earth, so that the moon now appears as a complete circular disc in the sky, and is said to be **full moon** (○). The full moon always culminates, or reaches its greatest altitude, in the south, at midnight. After full moon, during the last half of the revolution round the earth the same phases or appearances are retraced, but with the terminator on the west side of the lunar disc. For about a week the moon is again gibbous, as at the position F, and in little more than seven days after full moon it is again half-moon at the third or last quarter (☾), but with the convex side towards the east, and not to the west as at the first quarter.

In a few more days the crescent form appears again, and this crescent, curving eastward towards the sun about to rise, gets narrower and narrower until it disappears a little before the moon gets into conjunction with the sun once more. It must be particularly noticed that the crescent of the waning moon will be seen in the east of the sky to the west of the rising sun—that is, in the early morning—though the strong light of the sun does not let us see it in the sky after sunrise. The horns of this crescent, being turned from the sun, are in the opposite direction to the horns of the waxing moon, and in this case the dark part of the moon is on the west side (*see* fig. 145). The crescent at last becomes invisible, and shortly after the moon gets into conjunction with the sun again, a complete revolution with respect to the sun having been accomplished in about 29½ days. The moon remains invisible to the naked eye for about six days, though perfect conjunction with the sun lasts but a short time. This is because twilight renders the faint light of the very thin crescent close to the sun invisible about three days before and after new moon.[1]

The moon's age is the interval in days and hours since its last conjunction with the sun. Twenty-four hours after true new moon the moon is one day old; in another twenty-four hours two days old, and

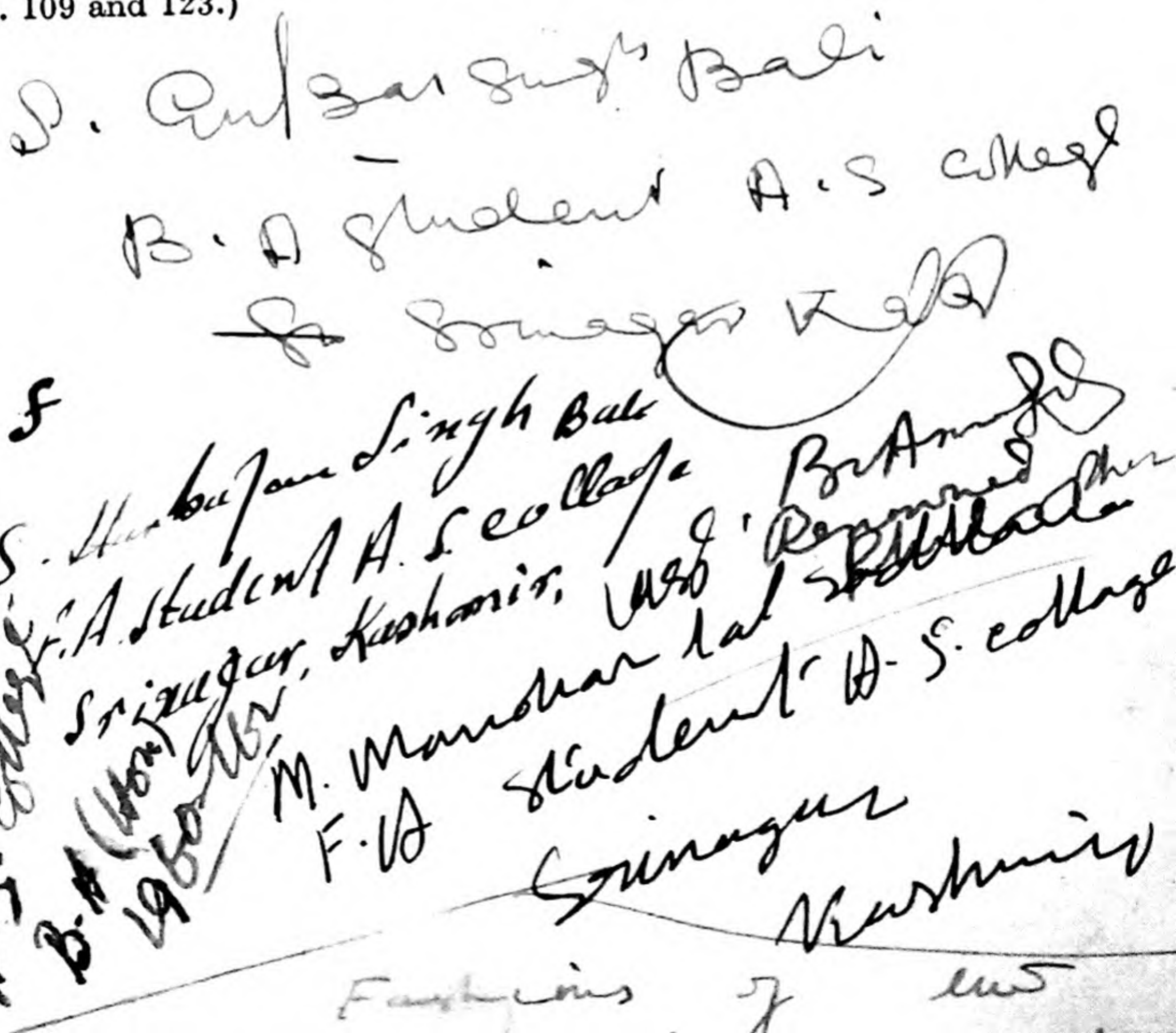
---

[1] The coming of the new moon, or the passage from one monthly revolution to another, is called a 'change' of the moon, though the word is sometimes used of other phases. The student must observe from one change to another day by day, and note the various positions of the phases at different hours of the night. Personal observation during a few months will fix in the mind the statements of the text, and save the reader from many common errors about the moon, such as speaking of a new moon in the sky at 10 o'clock of the night, or a full moon rising at midnight.

so on. As the lunar month is a period of 29 days 12 hours, we can easily find the moon's age at any phase, knowing the fraction of the orbit described at that phase. We can also reckon the time at which each phase is in the south on the meridian. At true new moon the moon's age is 0 days, and, as the sun and moon are in conjunction, they are on the meridian of a place at the same time; but the moon is entirely invisible, as its illuminated hemisphere is turned from the earth. At the first quarter the moon's age is about 7 days (7 days 9 hours). It is on the meridian of a place 6 hours after the sun, being 90° from the sun. At full moon the moon's age is $14\frac{3}{4}$ days, and it is on the meridian 12 hours after the sun, that is, at midnight, being in opposition, or 180° from the sun, which is then below the horizon in the north. Full moon, therefore, rises about 6 P.M., culminates at midnight, and sets about 6 A.M., being above the horizon all night when of most service. At the last quarter the moon's age is nearly $22\frac{1}{2}$ days (22 days 9 hours), and it is on the meridian 18 hours after (or 6 hours before) the sun.

The age of the moon for the waxing crescent, the waxing gibbous moon, the waning gibbous moon, and the waning crescent can easily be found by similar considerations.

96. **Eclipses.**—An eclipse of the moon is caused when the conical shadow thrown by the earth falls upon the moon's surface. This can only occur at full moon, and even then only when the moon is at or near one of its nodes, for at other times the earth's shadow falls north or south of the moon. An eclipse of the sun is caused when the moon's shadow falls upon a part of the earth. This can only happen at new moon, and when the new moon is at or near one of its nodes. (*See* figs. 109 and 123.)



GLOSSARY

Aborigines (Lat. *ab*, from ; *origo*, origin). The first or primitive inhabitants of a country known to history the original fauna and flora of a given geographical area.

Abyss, Abyssal (Gk. *a*, not ; *bussos*, depth, bottom). A bottomless gulf, anything very deep. Hence adj. *abyssal* relates to the deeper parts of the sea. Abyssal deposits are those occurring at great depths, such as Globigerina Ooze, Radiolarian Ooze, Diatom Ooze, and Red Clay.

Aërial (Gk. *aer*, air). Relating to the air. *Sub-aerial*, taking place beneath the air, as opposed to *sub-aqueous*, beneath the water.

Affluent (Lat. *ad*, to ; *fluo*, I flow). A stream or river flowing into another is termed an affluent or tributary.

Aiguille (Fr. *aiguille*, a needle). A needle ; applied in geography to the sharp peaks of lofty mountains.

Alluvium, Alluvial (Lat. *ad*, together ; *luo*, I wash). Matter, usually consisting of sand and mud, deposited by rivers. The soil of deltas and many river valleys is alluvial.

Altitude and Azimuth. The *altitude* of a heavenly body is its angular height (expressed in degrees) as measured on the arc of a vertical

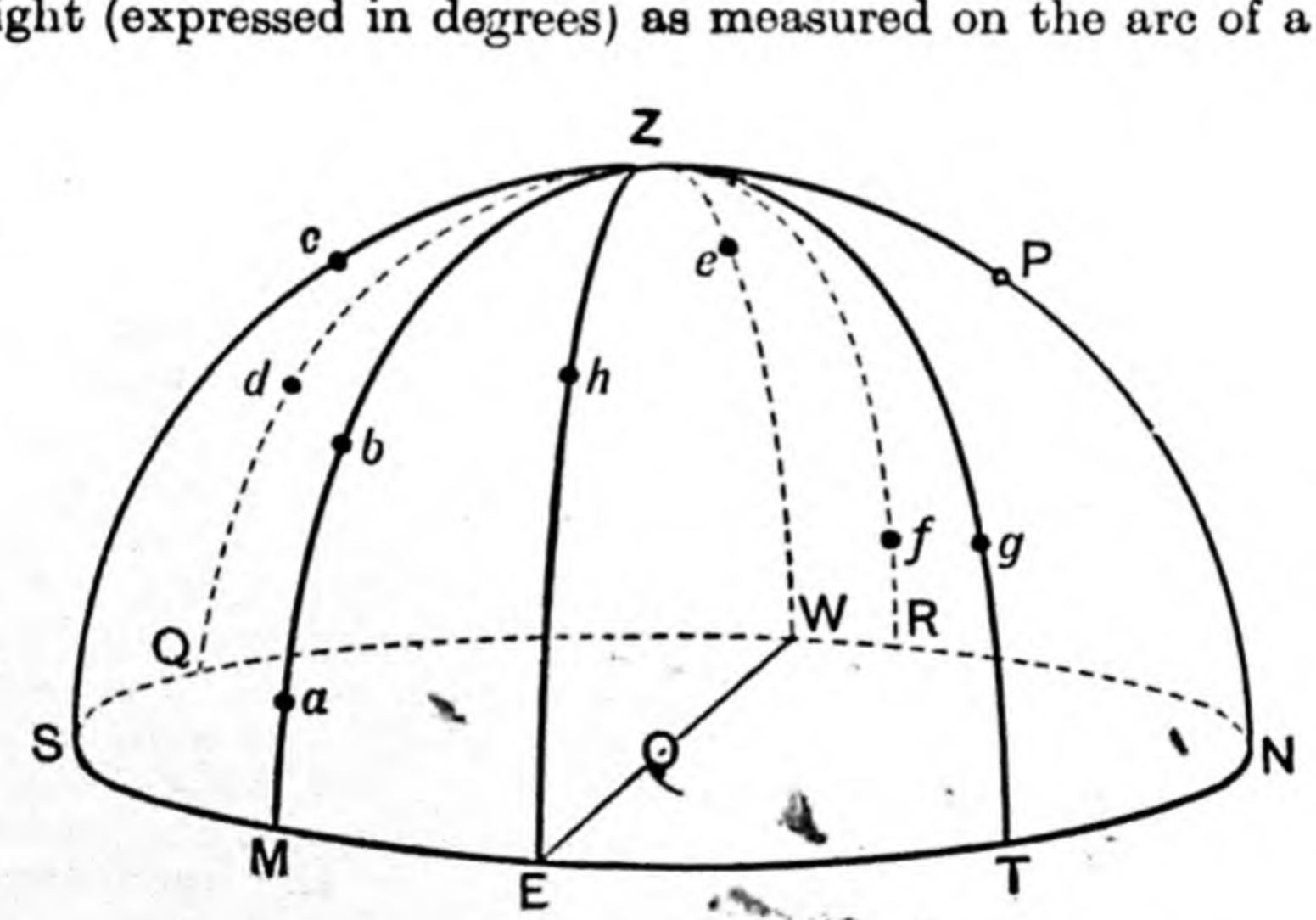


FIG. 111.—ILLUSTRATING ALTITUDE AND AZIMUTH. Star *a*, altitude arc *a*M, azimuth arc SM ; star *b*, altitude arc *b*M, azimuth SM ; star *c*, altitude *c*S, azimuth zero ; star *d*, altitude arc *d*Q, azimuth SQ ; star *e*, altitude *e*W, azimuth SW or NW ; and so on. (The value of the arcs of altitude and azimuth may also be expressed in degrees.)

circle drawn from the zenith through the body to the horizon. The *zenith distance* of a body is its angular distance on a vertical

circle from the zenith. Altitude + zenith distance = 90°. When we know the altitude or zenith distance of a star we do not know its position on the celestial sphere completely, as many stars may have the same altitude. We want another measurement to fix its angular distance from the south or north point of the horizon. The *azimuth* of a heavenly body is its angular distance from the south point of the horizon. It is measured on the arc of the horizon between the foot of the vertical circle drawn through the body and the point where the meridian meets the south point of the horizon. The measurement may be either east or west from the south point of the horizon provided the direction is specified, though it is often carried round the whole horizon through the west. Azimuth may also be measured from the north point of the horizon if the point and direction are clearly stated. A figure will make the definitions clear. Draw a semicircle to represent one-half of the observer's meridian. This will meet the horizon at the north and south points. Join the ends of this semicircle with an ellipse to represent the observer's circular horizon as seen obliquely from above and outside. Put in P for north pole at an angular height above the north point of the horizon equal to observer's latitude. O is the observer's position at the centre of the horizon. N, E, S, W are the cardinal points. Stars placed within the semicircle may then be regarded as somewhere on the celestial sphere, the observer being at the centre of the horizon with his zenith directly overhead. Owing to the daily rotation of the earth the altitude and azimuth of a body are constantly changing, the altitude being greatest when on the observer's meridian.

Antarctic (Gk. *anti*, against, opposite to; arctic). Applied to the regions round or near the South Pole.

Anti-cyclone (Gk. *anti*; *kuklos*, a circle). An atmospheric condition opposite to that of a cyclone; an area of high pressure from the centre of which the barometrical readings decrease in all directions; and from which gentle breezes blow spirally outwards. An anti-cyclonic system is usually accompanied by fine weather. (*See* fig. 24.)

Antipodal Points. The antipodal point or antipodes of any place is on the diametrically opposite side of the earth. It will therefore be on the corresponding parallel of latitude on the other side of the equator, but on the opposite half of the circular meridian that passes through the place (180° from the place). For example, London is in lat. 51° 30′ N. and long. 5′ W.; its antipodal point or antipodes is therefore 51° 30′ S. and long. 197° 55′ E. An island near this spot in the Southern Ocean is known as Antipodes Island. Rome lies in lat. 41° 53′ N. and long. 12° 28′ E.; its antipodes is therefore 41° 53′ S. and long. 167° 32′ W. (180° — 12° 28′). Sydney lies in lat. 33° 54′ S. and long. 151° 8′ E.; its antipodes is 33° 54′ N. and long. 28° 52′ W. A place on the equator will have its antipodes on the equator. If its long. is 79° W., the longitude of the antipodes will be 101° E.

Antipodes (Gk. *anti*, against; *podes*, the feet). Persons or places on diametrically opposite points of the globe.

Anti-trades. The name anti-trades (or Variables) is given to the upper air-currents that move from equatorial regions above the trade winds towards the poles. Thus in the northern hemisphere we find

that these upper currents above the N.E. trades and passing in the opposite direction—*i.e.* from the south-west—are proved to exist by the fact that dust, thrown to a great height from volcanoes in the trade wind region, has been carried many miles to the north-east in numerous cases. High clouds in this region are also seen to be carried by south-west winds to the north-east while the regular north-east trade wind is blowing below. About lat. 30° much of this upper air descends to the earth to form the prevailing south-westerly winds of the northern hemisphere and prevailing north-westerly winds of the southern hemisphere. These prevailing westerly winds at the surface are sometimes also called the S.W. anti-trades and the N.W. anti-trades, as in fig. 27, though it is perhaps better to call them the prevailing S.W. winds in the northern hemisphere and the prevailing N.W. winds in the southern hemisphere. (*See* also Question 74.)

Aphelion (Gk. *apo*, from ; *helios*, the sun). That point of a planet's or comet's orbit which is most distant from the sun ; opposed to *perihelion*.

Apogee. *See* ' Perigee.'

Aqueous (Lat. *aqua*, water). Watery, relating to water ; *e.g.*, aqueous rocks are rocks which have been formed by the action of water. *Sub-aqueous*, occurring under water, in contradistinction to *sub-aërial*.

Archipelago (Gk. *arche*, chief ; *pelagos*, the sea). The name first given to the Ægean Sea, separating Greece from Asia Minor, and studded with small islands. Hence it has come to mean any body of water abounding with islands, or the islands themselves, as the Malay Archipelago.

Arctic (Gk. *arktos*, a bear). Relating to the regions round the North Pole. The north pole of the earth's axis points towards a star (the Pole Star) in the constellation of the Little Bear, and hence *arctic* refers to anything connected with the pole, so, cold and frigid.

Atoll (a Malay word, *atol*). A coral island consisting of a ring of coral resting on the sides of a submerged hill, and having a central lagoon or lake. Such islands are very common in the Central Pacific (fig. 77).

Aurora Borealis (Lat.). A luminous appearance seen in the northern heavens, and so called from its resemblance to the *aurora*, or morning twilight. It usually shows itself as streams of light ascending towards the zenith, and stretching from the north towards the west and east, so as to form an arc. A similar light is sometimes seen by people in the southern hemisphere, and is known as the *Aurora Australis*.

Avalanche (Fr.). The sudden fall or sliding down of a mass of snow or ice from the steep slopes of a mountain.

Axis (Lat. *axis*, an axle). The imaginary line about which any rotatory body, such as the earth, turns.

Bar. A bank of sand or gravel at the mouth of a river or harbour obstructing the entrance.

Barometric Corrections. A barometer is an instrument used to measure the pressure of the atmosphere. (*See* Pars. 14 and 15.) To compare barometric pressures made at different stations *corrections*

must be made for (1) temperature and (2) for the height of the observing station above sea-level. The correction for temperature must be made because the mercury in the barometer expands with increase of temperature and contracts for a fall of temperature. Hence observations must be reduced to some standard temperature. The freezing-point of fresh water, 32° F. or 0° C., is taken for the standard temperature. The correction for height above sea-level must be made because as we ascend there is less air above and the barometer falls. (Par. 14.) Near the sea-level there is a fall of 1 inch for a rise of about 1,000 feet. A barometer can thus be used to measure heights, if we know the pressure at the sea-level and that upon the height. Thus if the barometer at sea-level shows 30 inches and on a hill 29·2 inches, the height of the hill will be 800 feet. At the foot of Ben Nevis the average height of the barometer is 29·85 inches; on the summit the average height is 25·30 inches, a fall of 4·55 inches. This makes the height of the mountain, taking a rise of 1,000 feet to result in a fall of 1 inch, to be 4,450 feet. The actual height of the mountain is 4,407 feet. The fall of the barometer shown in this case is at the rate of 1 inch for about 962 feet.

Barometric Gradient. In meteorology the term 'gradient' means the difference of barometric pressure per unit of distance, the difference being expressed in decimal parts of an inch per 15 nautical miles (or about 17 statute miles). Usually a gradient is expressed in hundredths of an inch per unit of distance, so that a gradient of 2 means a difference of pressure of 0·02 inch in 15 nautical miles. To calculate the barometric gradient between two places we must know the barometric readings at the two places at a given time; then the perpendicular distance between the isobars passing through the places (this is not always as the crow flies), and a little arithmetic will solve the problem. For example, a reading at Brest gave 29·38 inches when a reading at Penzance was 29·19—a difference of reading of 0·19. The perpendicular distance between the isobars passing through the two places was 113 miles. We then ask, if there is a difference of 0·19 inch in 113 miles, what will be the difference in 15 miles? The result is 0·025 inch. This is the barometric gradient. By drawing a line perpendicular everywhere to a system of isobars, regarded as a system of contours of barometric height, we could represent the gradient as we represent sections of land (fig. 80). A knowledge of the barometric gradient gives information as to the strength of the winds, for the force and velocity of the wind increase as the barometric gradient increases; that is, where isobars are drawn for differences of one-tenth of an inch the closer are such isobars, the stronger are the winds. A gradient is 'moderate' when it is not more than 0·01 inch. With such a gradient the wind velocity is about 9 miles an hour. A gradient is 'steep' when it is above 0·02 inch. At this gradient the wind velocity is about 20 miles an hour. For the relation of the *direction* of the winds to the isobars, *see* 'Weather Charts.'

Barrier Reef. A reef or ridge of coral rocks parallel to and at a distance from the shore, and having a navigable channel between. Off the north-east of Australia is the Great Barrier Reef.

Basin. The area drained by a river; used mostly when speaking of a large river, and then includes the entire area drained by the

main stream and its tributaries, the catchment-basin. The map (fig. 112) shows the basin of the river Thames. The word basin is also used as a geological term in a different sense and so a river basin is often called a *catchment basin*—where rainwater is caught.

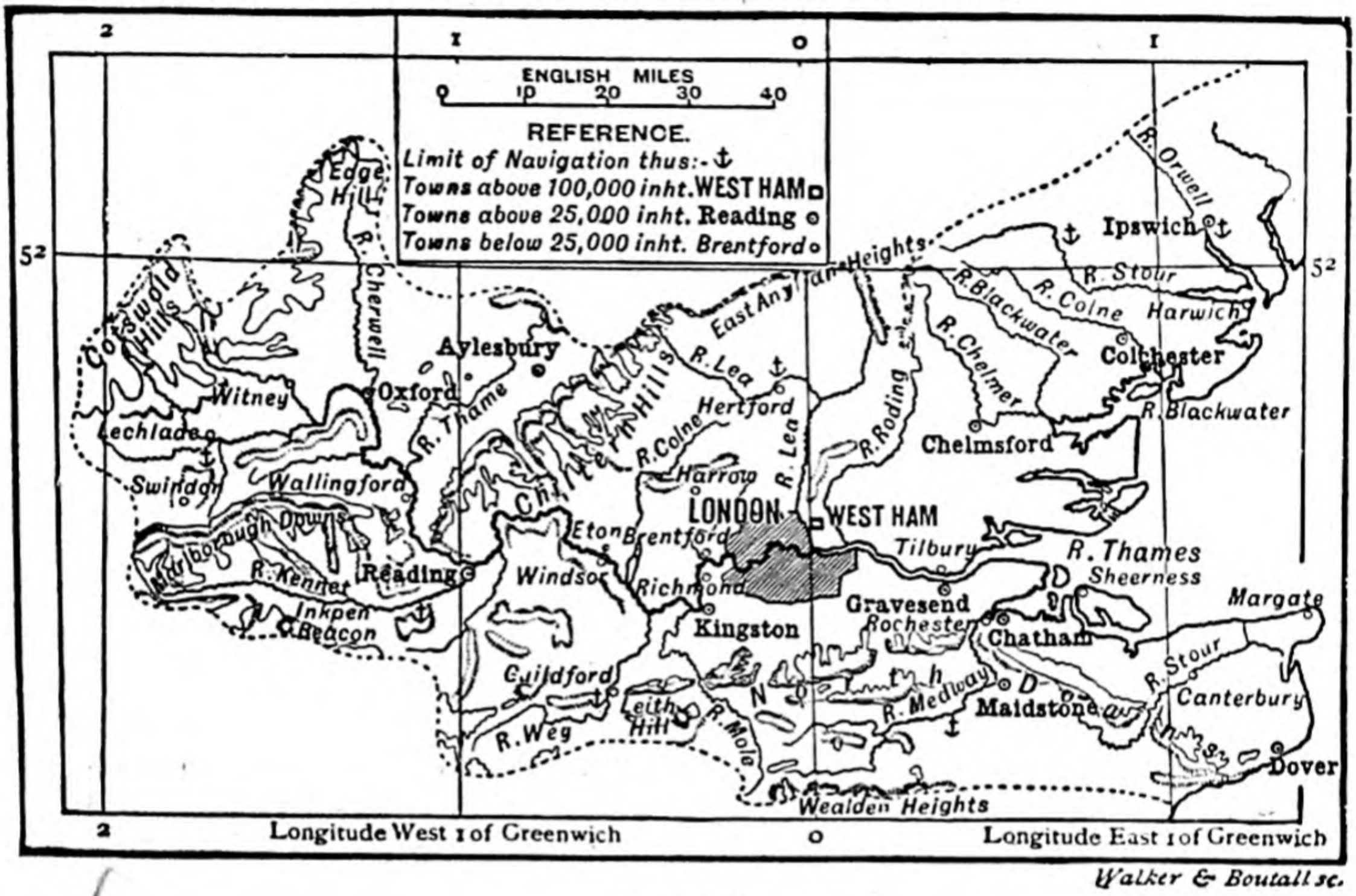


FIG. 112.

Bay. A part of the sea running into the land, having a wider opening than a gulf.

Beach. The name given to that part of the shore of the sea or of a lake which is washed by the tide and waves. It usually means the tract between high and low water mark, and consists of shingle, sand, or mud. *Raised Beaches* are beaches now above high-water mark owing to slow elevation of coast (Par. 50).

Bed. The bottom of a river or other stream; in geology, a layer or stratum of sedimentary rock, usually distinct from those which lie over and under it. Rocks that have been deposited by water occur in beds or strata, and these vary in thickness from a few inches to a hundred feet or more. Originally horizontal or nearly so, strata or beds have often become inclined or contorted.

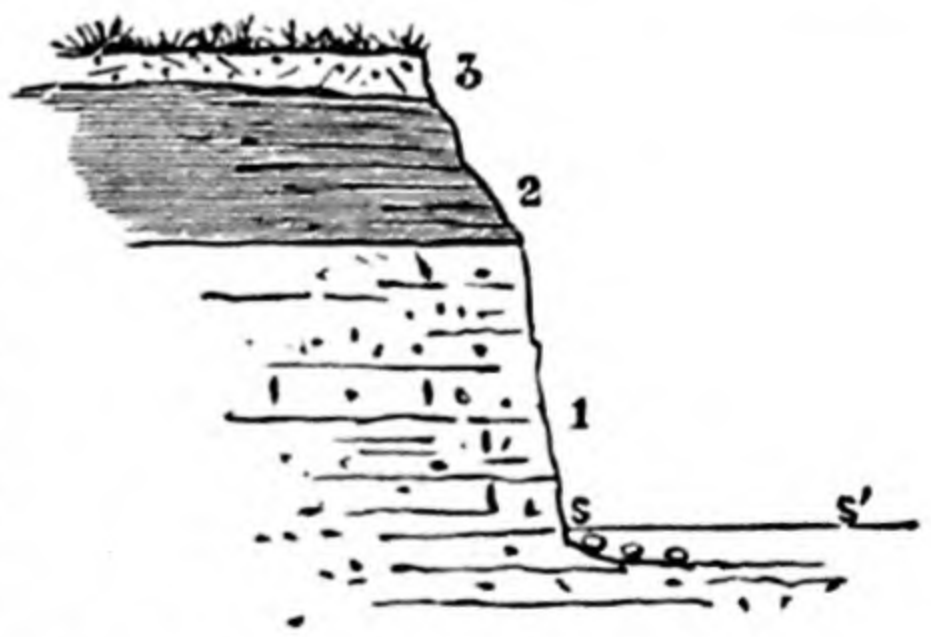


FIG. 113.—FLAMBOROUGH HEAD.
1, chalk; 2, clay; 3, soil and subsoil.

Bight (A.-S. *bugan*, to bend). A wide opening formed by a long and gradual bend of a coast-line; used especially in the names Bight of Benin and Bight of Biafra in Africa, and the Great Australian Bight.

Blizzard. A hurricane of cold wind and driving snow such as occurs in winter in the N.E. of North America ; a snow-blast.

Bluff. A high bank with a sharp, precipitous front.

Bog (Celtic *bog*, soft or moist). Wet, soft, spongy ground where the soil is composed of decayed vegetable matter.

Bore. The advancing wall-like front of the tidal wave as it ascends a river or estuary, the water then rushing up the channel with great violence and noise. The most celebrated bores are those of

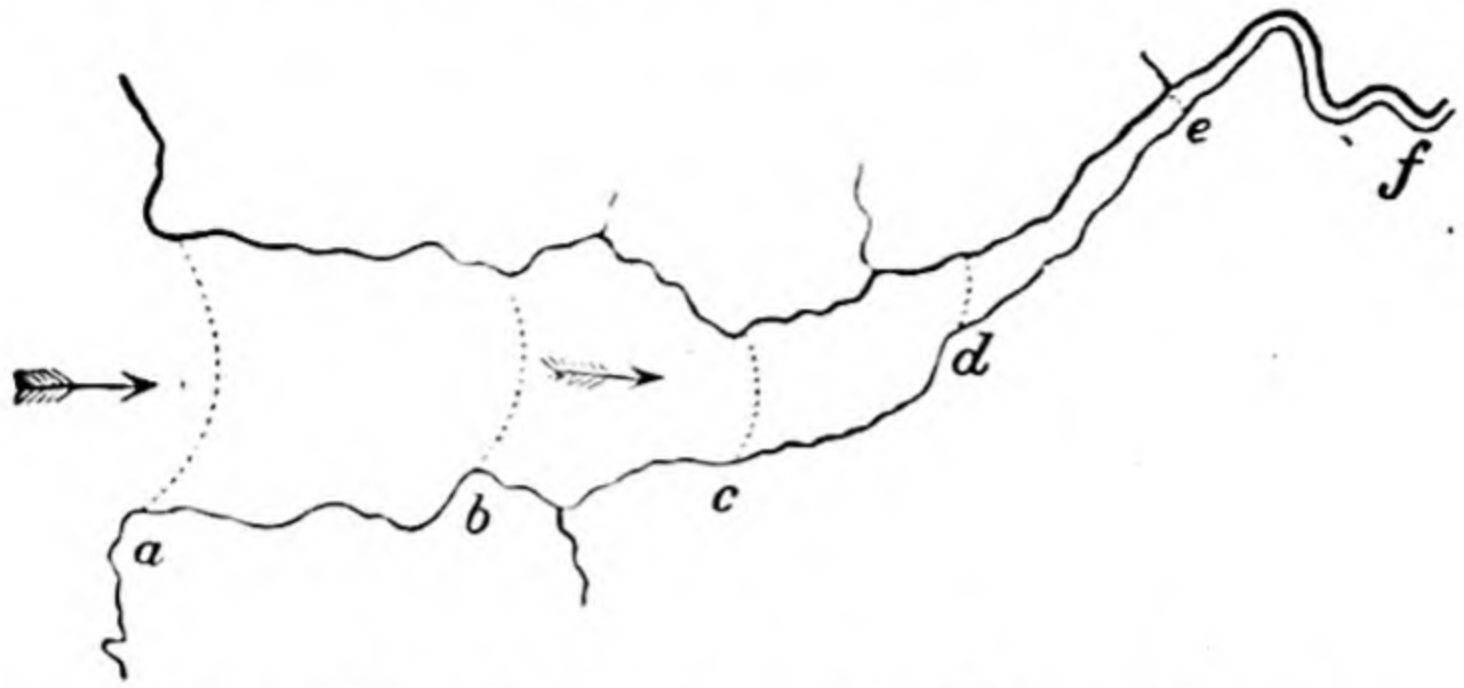


FIG. 114.—FORMATION OF TIDAL BORE.

The tidal wave rising successively higher at *a*, *b*, *c*, *d* and *e*, till it dies away at *f*.

the great Indian rivers—the Ganges, the Indus, and the Brahmaputra—which sometimes rise to a height of 12 feet. The Amazon also has a large bore, whilst that in the Bay of Fundy is very remarkable. In England, the Severn has the best-marked bore.

Boulder. A large, loose rock whose edges have become weather-worn and more or less rounded. *Erratic blocks* (Lat. *erro*, I wander) are boulders which have been transported by ice from their native bed, and deposited at a considerable distance.

Calcareous (Lat. *calx*, *calcis*, lime). Formed of calcium carbonate, or carbonate of lime. Chalk, marble, and coral are calcareous rocks.

Cañon (Spanish *cañon*, a tube or funnel). The name given to a deep gorge with precipitous sides, such as is found in the great plateau

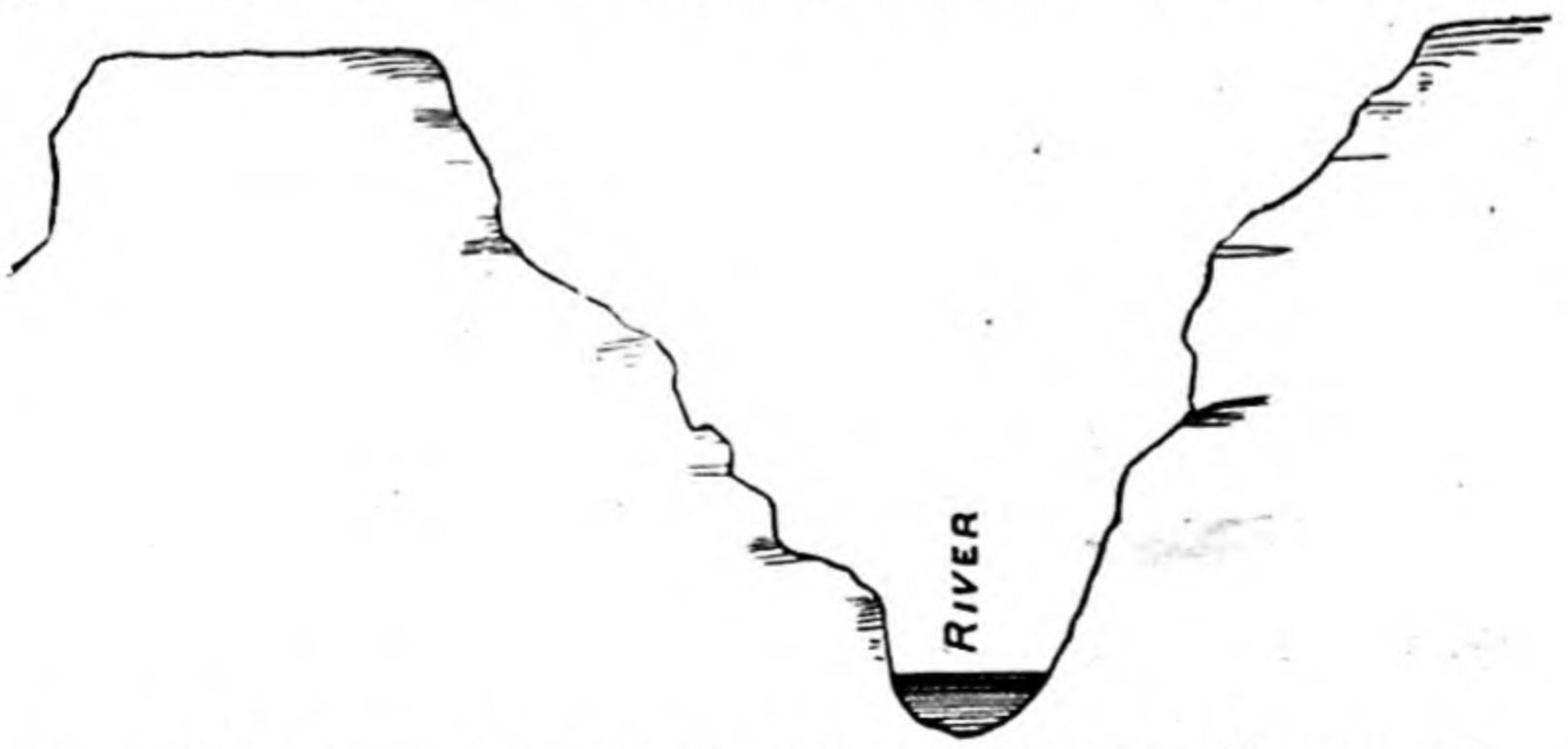


FIG. 115.—SECTION OF GRAND CAÑON IN COLORADO.

of Colorado. The Colorado River rises in a district of much rain, but passes through a district very much drier, and hence the sides

of the valley it carves out suffer but little from rain-action and remain steep, though carved into fantastic pinnacles and buttes by frost and other atmospheric agencies.

Cape (Lat. *caput*, a head). A piece of land jutting into a sea or lake beyond the adjoining coast-line. A headland, promontory, or ness.

Carbonic Acid. The name sometimes given to a constituent of the atmosphere; a gas which may also be obtained by burning charcoal or carbon in air, and which is expired by the lungs. A better name for the gas is carbon dioxide, and it always exists in the air in the proportion of about four parts in ten thousand. It takes a share in the weathering of rocks (Par. 53). The chemical composition is CO_2.

Cardinal (Lat. *cardo*, *cardinis*, a hinge). Hence something on which a thing turns, and so important.

Cardinal Points. The cardinal points (Lat. *cardo*, *cardinis*, a hinge) are the four chief points of the horizon, north, south, east, and west. The north and south line at any place on the earth is called the *meridian* line, and lies in the same direction as the geographical meridian of the place. The north point of the horizon is the point in which the meridian line meets the horizon towards the north pole of the heavens. The opposite point is the south point of the horizon. The east and west points of the horizon are the points where a line drawn through the observer's position at right angles to the meridian line meets the horizon. There are various methods of finding the true north and south or meridian line at any place, and thus fixing the cardinal points, for the east and west points are found by drawing a line at right angles through the north and south line. One of the simplest is by observing the noon-day shadow of a vertical rod, as explained in Par. 9, for the sun at noon is directly south, while at midnight it is directly north. A rough method of finding the north and south line is to direct the hour-hand of a watch to the sun. The south point will be midway between the hour-hand so directed and XII. At night we may find the meridian line by pointing a telescope to the Pole Star, or, more accurately, to the point about which the Pole Star appears to turn (fig. 101). Such a telescope would lie along the plane of the meridian, and the north point of the horizon is vertically beneath the celestial pole in our latitude. Again, a telescope pointing to any star when at its greatest altitude is pointing along the meridian, and the south point of the horizon is directly beneath a star when it is at its greatest altitude and transiting the celestial meridian. With the aid of a freely suspended magnetic needle or a magnetic compass the cardinal points may be found at any time, provided we know the angle of variation of the needle from the true north at the place of observation. The earth can be regarded as a great magnet. It has two magnetic poles, but their positions do not coincide with the geographical poles. The north magnetic pole lies in lat. 70° 50′ N. and long. 96° 46′ W., and the south magnetic pole about lat. 72° S. and long. 155° E. A freely suspended magnetic needle points to these poles. Hence at most places the magnetic needle does not point to the geographical pole, so that the magnetic north and south line, or *magnetic meridian*, lies a certain number of degrees east or west of the true north and south line, or *geographical meridian*. This deviation

of the magnetic needle from the true north and south line is called the *declination* or *variation* of the needle. In the British Isles the needle points west of true north. The deviation ranges from 16½° W. in the south-east of England to 24° W. in the west of Ireland.

To use the magnetic needle for finding the true north and south line allow any freely suspended horizontal magnetic needle to come to rest. Draw a line on the floor or on a table to mark out the magnetic meridian thus indicated by the needle. Through the point underneath the point of suspension of the needle draw another line, making with the magnetic meridian an angle equal to the magnetic declination of the place. This is the true north and south line, or geographical meridian, of the place. Another method is to obtain a pocket compass. This is a small magnetic needle pivoted over the centre of a fixed card, the whole enclosed in a box or case with a glass front. Place the compass on a horizontal surface, and let the light needle within the case come to rest. Now move the compass until the line marked N S on the fixed compass-card makes an angle with the compass-needle equal to the declination of the place—*i.e.* so that the line N S is the declination number of degrees to the east of the compass-needle for this part of the world, arranging that the point N on the card is at the required angular distance from the marked or north end of the needle. The point N is then pointing to the geographical north, and the direction or bearing of any object can be fixed from the 'points' indicated on the card. The figure shows the compass as used at a place in Europe where the declination is about 14° W. Note the names of the compass points on the needle, each of which is 15° from the next. Each of these subdivisions can be further subdivided. Thus the point halfway between N and N N E is N by E (north by east); that which is halfway between N N E and N E is N E by N (north-east by north); and so on. The whole of the thirty-two points of the compass can be thus distinguished.

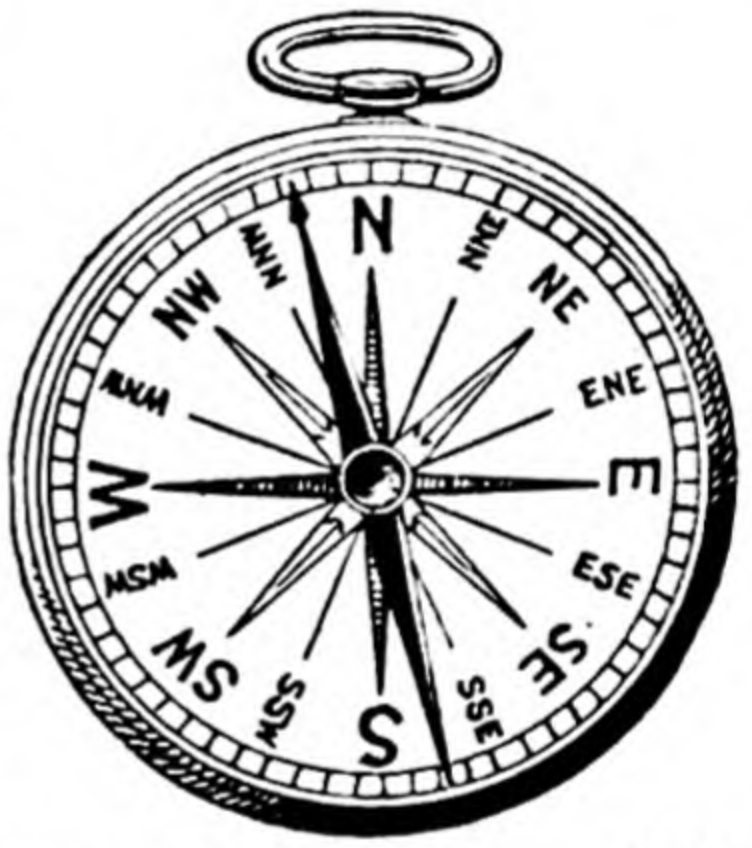


FIG. 116.—POCKET COMPASS.

Carnivora (Lat. *caro, carnis*, flesh; and *voro*, I devour). The name given to the order of mammalia that live entirely on flesh, such as the lion, tiger, etc.

Cascade (Lat. *cascare*, or *casus*, fall). A fall of water in a river or other stream. *A Cataract* is a larger waterfall than a cascade, but may not be so steep.

Channel (Lat. *canalis*, a water-pipe, a canal). The bed of a stream or river; a part of the sea constituting a passage between two pieces of land, though broader and longer than a **Strait.**

Climate (Gk. *klima*, a slope, inclination). The general state of the atmosphere of any place in regard to heat and moisture, and the other conditions that exert an influence on animal and vegetable life. It is the average condition of the weather. A place having

a fine dry climate may have bad weather on a particular day. The climate of a place, as indicated by its mean annual temperature, its mean summer temperature, mean winter temperature, and atmospheric moisture, depends chiefly on latitude; but the effect of latitude may be considerably modified by ocean currents, prevailing winds, and distance from the sea; while an increase or decrease in height above the sea-level has nearly the same effect as an increase in latitude (*see* Chapter VII.).

Climatic Zones and Regions. The five belts or bands of the earth's surface bounded by certain parallels of latitude, as fixed by the apparent position of the sun during the year (*see* below, 'Zones') are sometimes called *climatic zones* or *heat zones*, because of the various amounts of heat each receives. The greater the angle at which the sun's rays reach the earth, the greater is their heating effect (Par. 7), owing to the less amount of surface over which a beam is spread (fig. 25) and to the less air it has to pass through (fig. 16). In each of the five zones there are considerable differences of temperature at the sea-level, so that they are sometimes subdivided, and we get the eight climatic zones given in Par. 66. As examples of a sub-tropical climate, a warm, genial and salubrious climate between tropical and temperate, we may mention South Africa, Northern Egypt, California, and South Australia. But since the temperature of the air depends not only on latitude, but on proximity to the sea, altitude, prevailing winds, etc., and since climate includes other things besides temperature other divisions of the earth into *climatic regions* are sometimes made, *e.g.* desert climates, mountain climates, coast climates, dry climates, etc. (*See further* Chapter VII. and Question 179.)

Cloud-burst. A violent downpour of rain in large quantity over a very small area, such as sometimes descends from the funnel-shaped cloud in a tornado in certain parts of the United States (*see* Par. 23).

Col (Fr. *col*, neck). A low ridge or divide between two mountain masses.

Cold Wall. The boundary-line in the North Atlantic where the cold Arctic current meets the Gulf Stream (*see* Par. 39), or the current itself.

Condensation (Lat. *condenso*, I make thick, or dense). The change or conversion of a vapour or gas into a liquid or solid form, brought about either by cold or pressure, or both. Atmospheric water-vapour condenses as dew, fog, rain, snow, and hail.

Conglomerate (Lat. *con*, together; *glomero*, I gather into a ball). A rock made up of rounded and water-worn pebbles cemented together; sometimes called 'pudding-stone.'

Continent (Lat. *con*, together; *teneo*, I hold). One of the larger masses of land of the globe containing several countries (Par. 44).

Contour (Fr. *con*, together; *tour*, a turn). The outline of a body, or the line that defines or bounds anything; the horizontal configuration of a country.

Contour-lines are lines joining points of equal elevation on a surface, and are often used on maps for this purpose. Where the slope is steep the lines become crowded together, and *vice versa* (Chapter X.)

Coral. The gelatinous animal or marine polyp that forms coral rock; also the name of the substance formed, which consists mainly of calcium carbonate. Reef-building corals are only found near the surface in the clear water of warm seas. They secrete the rock from the sea-water, and this remains, and accumulates on the death of the animals (Par. 47).

FIG. 117.—SMALL PIECE OF CORAL, MAGNIFIED, SHOWING THE EXTENDED TENTACLES OF THE CORAL POLYPS.

Coral Reefs, or Coral Islands, is the name given to certain low islets which are composed of the calcareous skeletons of the coral polyps. An **Atoll,** or typical coral island, consists of a somewhat ring-shaped reef enclosing a lagoon. **Barrier reefs** are reefs surrounding islands or bordering mainlands, from which they are separated by a navigable channel. **Fringing Reefs** are ridges of coral rock closely fringing the land. Reef-building corals do not flourish in water having a lower temperature that 68° F., and hence reefs are only found in tropical and sub-tropical seas.

Cordillera. A chain or ridge of mountains; applied to the parallel chains of the Andes in South America, and also to the series of ranges embraced between and including the Rocky Mountains and Sierra Nevada chain in Western North America.

Coulée (Fr. *culer*, to flow). A dry ravine or gulch; in geology, a stream or flow of lava.

Crater (Gk. *crater*, a cup or bowl). The funnel-shaped opening at the top of a volcanic cone, through which gases, ash, and stony matter are or used to be ejected. Its walls are usually rugged and rent, and at its bottom is the tube or pipe leading inwards. This may, however, be plugged up by solidified lava.

Crevasse. A rent or fissure in a glacier, which may be of greater or less depth, and from a few inches to many feet in width, and caused by strains in the moving ice.

FIG. 118.—CROSS-SECTION OF A GLACIER, SHOWING MIDDLE AND LATERAL MORAINES AND CREVASSES. (*m*, Median Moraine, *l*, Lateral Moraines.)

Crust (Lat. *crusta*, the hard surface of a body). In geology, the external shell of the earth, or that thickness of the earth's surface which can be examined.

Cyclone (Gk. *kuklos*, a circle). The name given to an atmospheric disturbance which in the winds blow spirally inwards towards a central region of low barometric pressure. Cyclones are usually accompanied by bad weather—rain and squalls—and move off a district more quickly than anti-cyclones. Fig. 119 shows a cyclonic area covering Wales and the surrounding isobars. The number of barbs to the arrows increases with increase in the strength of the wind. (*See also* 'Weather Charts.')

Débris (Fr.). Fragments, ruins ; in geology, a mass of rocky fragments worn away, and sometimes collected together at one spot—*e.g.* the débris at the base of the cliff.

Declination. In astronomy, the declination of the sun or other heavenly body is the angular distance north or south of the celestial equator, the celestial equator being the great circle, 90° from the celestial poles. The sun reaches its greatest declination north at the summer solstice, its greatest declination south at the winter

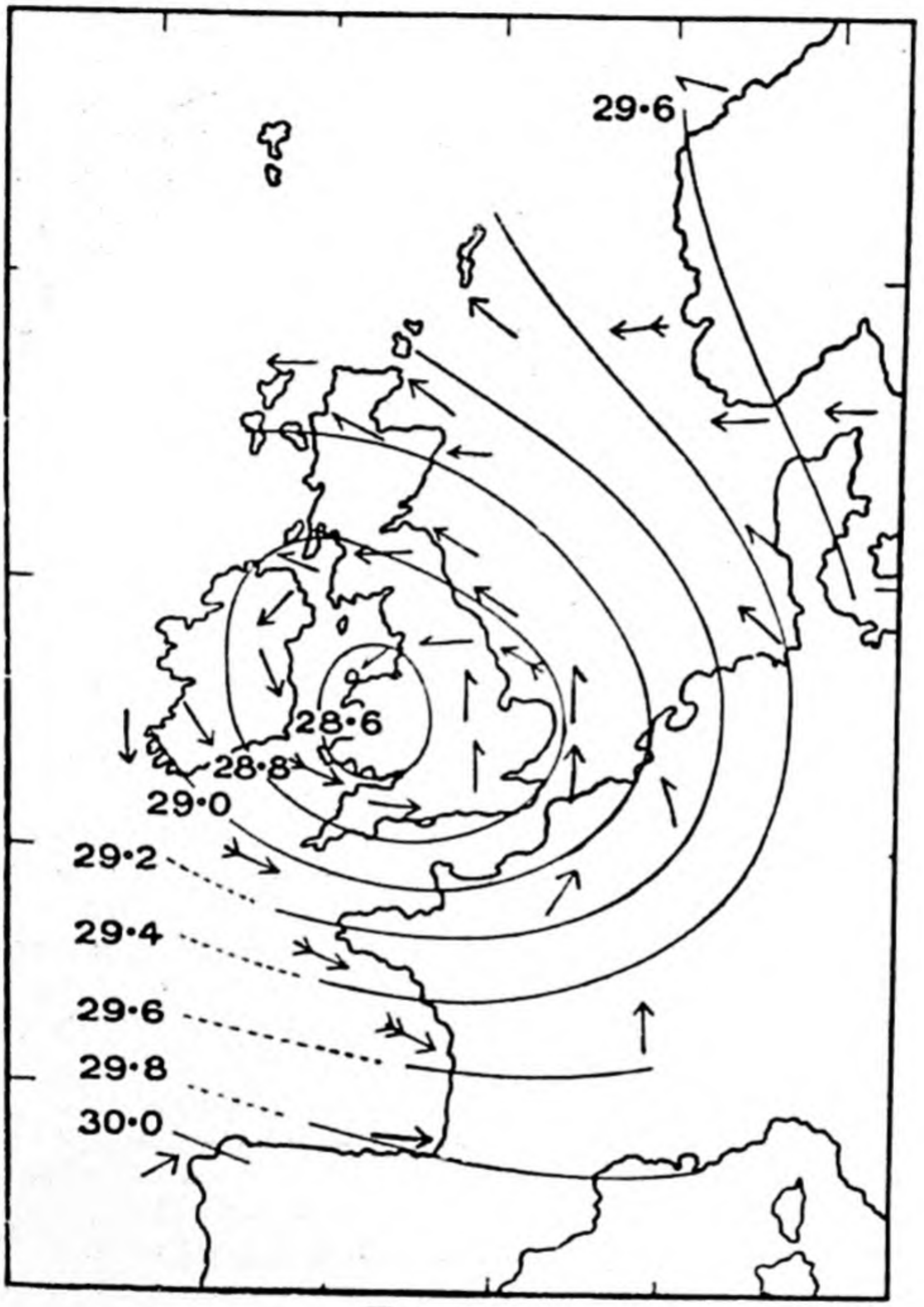


FIG. 119.

solstice. Also the angle indicating the deviation of the compass needle from the true north.

The declination of the sun or of a star is its angular distance north or south from the celestial equator measured on the arc of a meridian passing from the celestial pole to the celestial equator. It corresponds to latitude on the earth ; when the sun is on the equator at the equinoxes its declination is zero. **Right ascension** is the equivalent of longitude.

Degradation (Lat. *de*, down ; *gradus*, a step). The gradual wearing down of rocks, strata, etc., by the action of water or the air.

Degree (Lat. *de*, down; *gradus*, a step). For the convenience of measuring angles we can divide the circumference of a circle into 360 divisions, each of which is called a *degree* (°). Each degree is subdivided into sixty minutes (′), and each minute into sixty seconds (″). (Do not confuse these with minutes and seconds of time.) The latitude and longitude of a place are both expressed in degrees. Thus, the Observatory of Cape Town is situated exactly 33° 56′ 3″ S. lat. and 18° 28′ 41″ E. long.

Delta (Gk. Letter Δ). The land formed of alluvial mud deposited at the mouth of a river, where the waters are sluggish, and at whose mouth there are no strong tides or currents to remove the deposit. After a time this deposit causes the stream to divide into branches (the place of division being the *head* of the delta), between which the material continues to be formed and rise above the water level, often acquiring the form which gives it its name, after the fourth letter in the Greek alphabet. Most deltas extend seawards, that of the Po in Northern Italy advancing into the Adriatic 70 yards per annum. Deltas may also be formed where a river, having a large amount of sediment in suspension, has its course suddenly checked by entering a lake. Such a delta is called a **lacustrine delta,** a good example of which is formed where the Rhone enters Lake Geneva in Switzerland.

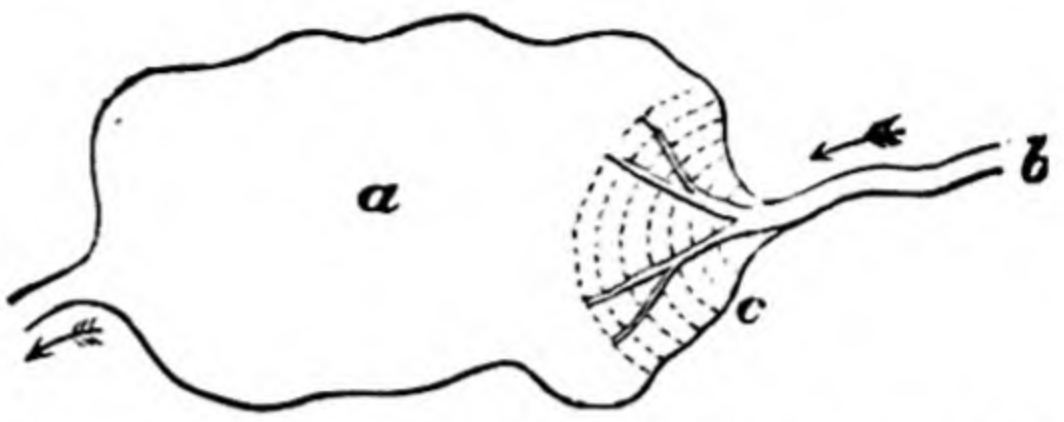


FIG. 120.—STREAM RUNNING INTO A LAKE AND FORMING A DELTA.

a, clear water of lake; *b*, muddy water of stream; *c*, lacustrine delta.

Density (Lat. *densus*, thick). The compactness or closeness of the particles of a body.

Denudation (Lat. *de*, down; *nudo*, I lay bare). The wearing away and removal of a part of the earth's surface by rain, wind, etc., so as to lay bare what is underneath it. A distinction is usually made between *sub-aerial* and *sub-marine* denudation.

Deposit (Lat. *de*, down; *positus*, placed). Matter which has been thrown or settled down from suspension in a fluid, such as muds, sand, etc.

Desert (Lat. *desertus*, abandoned). A region devoid of vegetation and uninhabitable, usually owing to the absence of rain.

A desert is a rainless or almost rainless district on which only a few specially adapted plants and animals can live. Most deserts are either plains or plateaux covered in great part by drifting sand. In some a few hills or mountains rise high enough to chill the air to such a degree that rain falls at times. Trees (as date palms) are then found on the slopes and at the foot. Such fertile spots are *oases*. The rainfall runs off quickly, soon evaporates, or is lost in the sand, the streams being but temporary. The wind blows the sand into dunes, ridges and troughs, and occasional sand storms occur. Except in the fertile spots or the parts rendered fruitful by irrigation, the population consists of nomad tribes. Most of the deserts are in the trade-wind belts north or south of the equator, for these winds passing towards the equator from

higher latitudes become warmer and drier on passing over great lowlands like the Sahara. If lofty mountains cross the path of such winds they will be made to ascend, to become cold, and to give up all their moisture, so that the lee side will be quite dry, as in Southern Peru, a district in the south-east of the United States, and a great part of Central Australia. Coast districts washed by cold ocean-currents and traversed by cool winds from higher latitudes also give rise to desert conditions, as witness the Namib Desert in South-west Africa. Map 3 shows the position of the chief deserts, which include the Sahara, parts of Arabia, and the belt through Turkestan to Gobi, besides deserts in Australia, the Kalahari desert in South Africa, a desert in Southern Peru, etc. A desert climate is extreme—that is, shows a great range of temperature, for there is hardly any cloud or water vapour to screen the surface from the sun by day or to check radiation by night. Hence the daily range of temperature is great, so also is the annual range. Desert vegetation consists mainly of spiny grasses and thorny cactuses. The term desert is sometimes used to include *tundras* and the icy regions round the poles.

Detritus (Lat. *de*, down ; *tritus*, rubbed). Any broken material worn or rubbed off masses of rock. Its nature will depend on its source ; it may consist of sand, mud, gravel, etc.

Dew. Dew is moisture condensed as small drops from the atmosphere on the surface of bodies and ground (*see* Par. 25).

Dew-point is that temperature of the air at which dew begins to be deposited. (*See* 'Humidity'.)

Disintegration (Lat. *dis*, down ; *integer*, whole). The wearing down of rocks by the slow action of frosts, rain, and other atmospheric agencies.

Divide (Lat. *divido*, I separate). A term sometimes used for a watershed. A river basin includes all the land surface drained by a river and its tributaries, *i.e.* by a river system. The boundary between the basin of two adjoining rivers or river systems is called a divide,

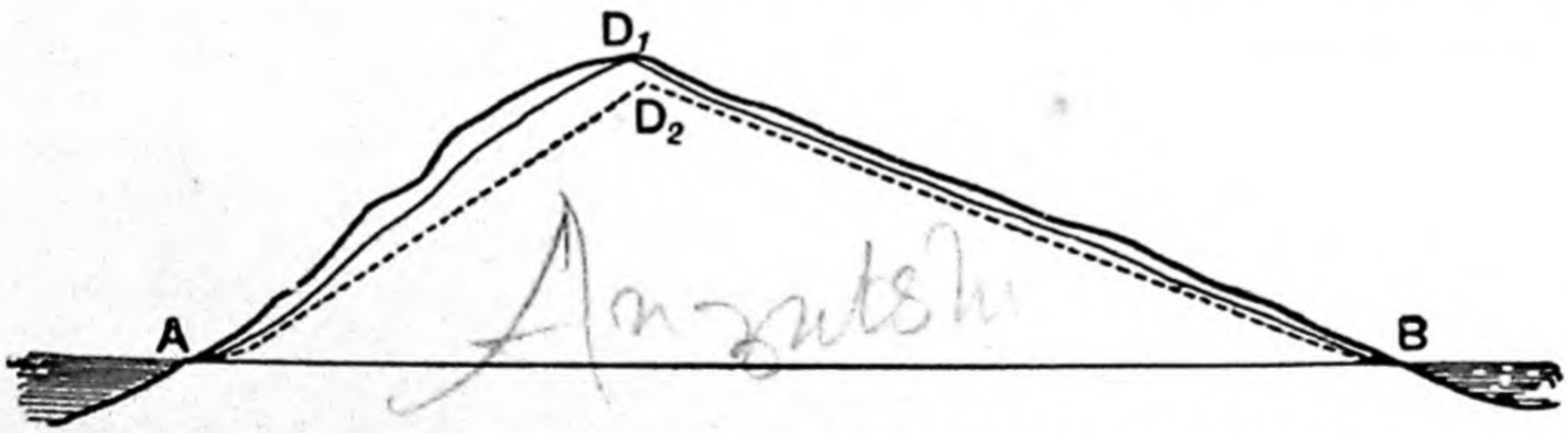


FIG. 121.—DIAGRAM ILLUSTRATING THE SHIFTING OF A DIVIDE OR WATER PARTING.

because the water falling as rain is there divided, part going to one stream and part to another. A divide or watershed is thus the higher land that forms the water parting between two river basins. It may be the crest of a high ridge like that of a house, or a nearly flat-topped plain like the roof of a railway carriage. A divide or water parting may shift its position. With a steeper slope on one side than on the other, the stream on the steeper slope, if other conditions are equal, will wear away its bed both at the source

and on the slope more quickly than the river on the gentle slope. It will thus work its way at the source farther back, lengthening its stream and drawing to itself some of the waters that ran down the gentler slope. In fact in this way a stream may capture a tributary from another stream. Fig. 121 shows a profile section of a hill with a steep slope on one side and a gentle slope on the other and streams (the continuous line below the outline of the hill) running down the slopes D_1 A and D_1 B. The stream on the steeper slope erodes more quickly than the other, making a deeper bed, and works the divide to D_2, the stream then following the course of the broken lines. The process goes on more and more slowly until the two slopes are nearly the same. In this way the stream on the steeper side captures water that originally would have run down the gentler slope. Other arrangements of land, as where one stream runs over nothing but soft beds, while another has hard rocks in its course, lead to a divide, moving back and seizing tributaries that formerly ran into some other stream. In mountainous areas a divide may have a very sharp edge and is then called an *arête*.

Doldrums. The name given to certain parts of the ocean near the equator in which sailing ships were often detained by calms, squalls, baffling winds, etc. The 'Doldrums' lie between latitude 5° S. and 15° N., slightly changing their position with the season of the year (*see* fig. 27).

Downs. The term applied to the rounded, dry hills of chalk in the South of England, which form natural pastures, and are largely devoted to sheep-rearing, also to similar areas in other parts of the world.

Drainage Areas. The land area drained by a river system, that is by a river and all its tributaries, may be called the basin or drainage area of that river. But the term 'drainage area' is used in speaking of the great oceans of the world. Thus we speak of the drainage area of the Arctic Ocean, etc. There is also an *inland drainage area*, the land of which does not send its waters into any real sea. Owing to the fact that the mountains of America are near the Pacific Coast, so that there is a short slope to the Pacific and a long slope to the Atlantic, three-fourths of the New World is drained into the Atlantic. Long slopes in Europe and Africa also incline to the Atlantic. The Atlantic drainage area, including the Mediterranean, is thus more than one-third of the land of the earth. In Asia the long slope is towards the north, so that the Arctic drainage area is nearly one quarter of this continent. Add to this the basins of the rivers that run into the Arctic Ocean from Europe and North America, we find that the Arctic drainage area is altogether about one-sixth of the land of the world. The drainage area of the Pacific is only about one-seventh of the land of the world. The drainage area of the Indian ocean is a little less than one-seventh. It includes that of some rivers in Africa, as well as the rivers of India and Mesopotamia. The *inland drainage* of the world is nearly one-fifth that of the world. It includes the drainage area of some large rivers that enter inland lakes, as the Caspian, Dead Sea, Sea of Aral, the Great Salt Lake of Utah, and Lake Tchad, as well as streams that run intermittently, and are lost by evaporation, or in a desert. Asia and Africa are the continents with large areas of inland drainage.

Dunes (A.-S. *dun*, a hill). Mounds or hills of loose sand heaped up by the winds on the sea coast. They often extend for miles, and form a series of well-defined ridges or crescent-shaped hillocks running in a direction at right angles to that of the prevailing wind.

Dust. Atmospheric dust consists of fine salt particles from the ocean spray, volcanic dust, meteoric dust, and the dust of combustion This dust plays an important part in the condensation of the aqueous vapour of the atmosphere, forming a nucleus on which the water-vapour condenses as mist, rain, etc. It also aids in scattering light. (*See* Par. 26.)

Dyke. An embankment thrown up for the purpose of keeping back the sea or a body of water ; *e.g.* the dykes of Holland. Used in

[*Crown Copyright.*

FIG. 122.—DYKE OF IGNEOUS ROCK LAID BARE BY DENUDATION.

Reproduced from a photograph supplied by the Director of the Geological Survey of Great Britain by permission of the Controller of H.M. Stationery Office.

geology to denote the intrusive masses of igneous rock that have been forced in a molten state into a fissure in the strata and there solidified.

Earthquake. A more or less violent vibration of the earth's crust, produced by some internal force. The instrument used for measuring the intensity of the shock is called a *seismometer*.

Eclipse (Gk. *ekleipsis*, a failing, disappearance). The disappearance or darkening of one body in the shadow of another. An eclipse of

the moon happens when at opposition or full moon the earth's shadow falls upon the moon. An eclipse of the sun happens if at conjunction or new moon a part of the earth passes into the shadow cast by the moon. Eclipses can only happen when the moon is at or near one of its **nodes.** (*See* Chapter XIII).

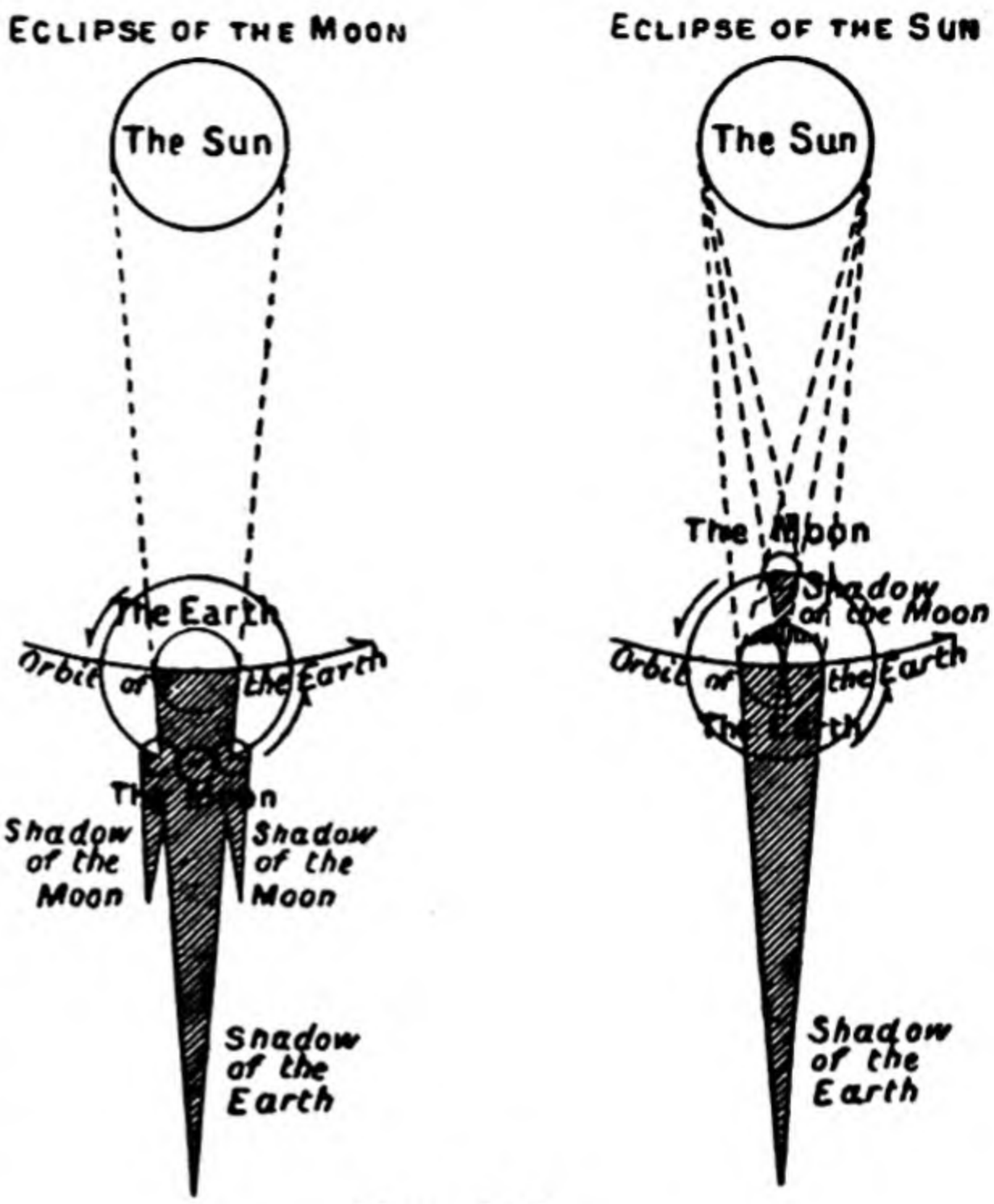


FIG. 123.

Ecliptic. The great circle which the sun appears to describe round the heavens in a year. The plane of the ecliptic is the plane passing through this circle, *i.e.* the plane in which the earth's orbit lies.

Equator. The equator is the circle drawn round the earth midway between the two poles, and dividing the surface into two equal hemispheres, the northern and the southern. At places on the equator the days and nights are of exactly the same length (twelve hours each) all the year round, and hence the equator is also termed the *equinoctial line* (Lat. *equus*, equal ; *nox*, *noctis*, night).

Equinox (Lat. *equus*, equal ; *nox*, night). The time when the sun is vertically overhead at noon on the equator, making day and night everywhere of the same length. There are two equinoxes—the vernal or spring equinox on March 21, and the autumnal equinox on September 22.

Erosion (Lat. *e*, out of ; *rosus*, gnawed). The gradual wearing away of rocks by water and other agencies.

Erratic Blocks. *See* 'Boulder.'

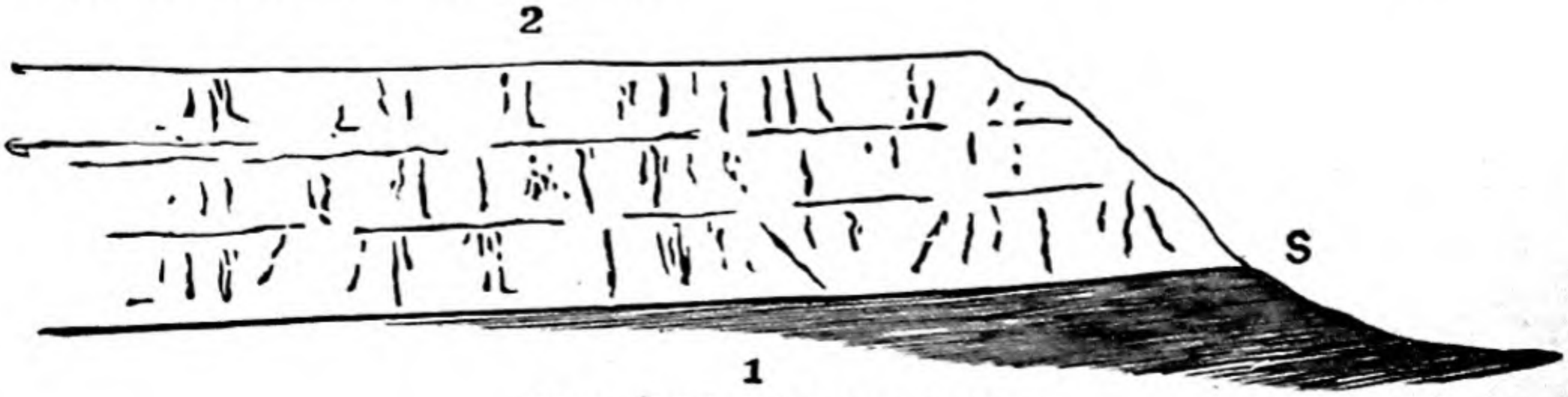


FIG. 124.—ESCARPMENT.

Chalk (2) resting on the Gault clay (1). S, position of the springs along the foot of the escarpment.

Escarpment (Fr. *escarpe*, steep). The abrupt, steep face of a ridge of land from which the rocky beds slope away in a long incline. (*See* figs. 124, 132.)

Estuary (Lat. *æstus*, the tide). That part of the mouth or lower course of a river affected by the tide where it opens out into an arm of the sea.

Evaporation (Lat. *evaporo*, I send off as vapour). The conversion of a solid or liquid into a gas or vapour. Strictly speaking, evaporation takes place only at the *surface* of a liquid, and is thus distinguished from ebullition or boiling, which takes place *within* the liquid.

Exotic (Gk. *exotikos*, foreign). Any plant or tree introduced from a foreign country, *i.e.* not native or indigenous.

Fathom. An English measure (6 feet) used in measuring depths of water.

Fauna. The name given to the entire group of animals living in a given area or at a given time.

Ferrel's Law. The following generalisation made by Prof. Ferrel is known as Ferrel's Law : *If a body moves in any direction on the earth's surface, there is a deflecting force arising from the earth's rotation, which deflects it to the right in the northern hemisphere, but to the left in the southern hemisphere.* The law helps to explain the direction of winds (Par. 20) and ocean currents (Par. 38). The law applies to all bodies moving on the earth's surface. It thus accounts for the fact that the rivers of the northern hemisphere press as a rule more heavily against their right bank, cutting it back into a cliff, while the left bank is left low and flat.

Ferruginous (Lat. *ferrum*, iron). Of the colour of iron rust ; of the nature of or containing iron.

Fiord. A deep indentation of the land forming a narrow arm of the sea, with steep slopes on each side. The coast of Norway contains a large number of these fiords, probably formed by submergence of land-valleys.

Firth, or Frith. A channel or arm of the sea, as the Pentland Firth. Used in Scotland to denote an estuary.

Flood Plains. A flood plain, or alluvial plain, is fertile land on each side of the lower course of a river, as it is exposed to overflow,

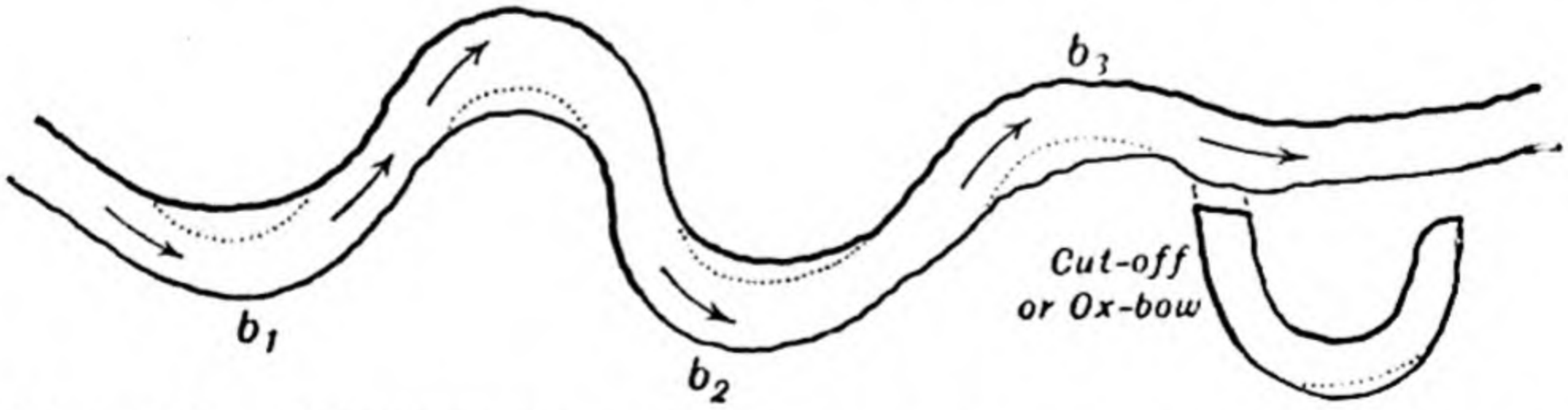


FIG. 125.—MEANDERING RIVER CUTTING AWAY ITS BANKS AT b_1, b_2, b_3, AND DEPOSITING SEDIMENT OPPOSITE.

and a deposit of alluvium in the time of flood. Such a plain is in reality the widest part of a river valley, the valley in this part of a river course having usually been widened by the slowly moving stream meandering from side to side, cutting deeper into the

concave shore and depositing sediment near the convex shore. The course of a typical river may be divided into three parts: (1) A Torrential Track; (2) A Valley Track; (3) A Plain Track. In the torrential track the slope is steep, and the dashing waters, aided by the stones and other solid matter they carry, erode the bed rapidly, and form a gorge or valley with deep sides. In the valley track the slope is moderate, but erosion of the bed still goes on, and this in conjunction with the weathering of the sides leads to a wide valley, with terraces of river gravel at various heights (Par. 54*a*). In the plain track the slope is gentle, although the stream still carries on fine sediment and matter in solution, and deposits material on the bed. Little obstructions cause it to wind from side to side, cutting into the concave shore and depositing on the convex side. Widening of the valley thus goes on, and the bed of the stream is raised. A narrow neck between two curves may get cut through, and the ends of the loop filling up there is left at last a curved lake cut off as an *oxbow* (fig. 125). The widened river valley here forms a stretch of flat land on each side called a flood plain. The bed of the stream becomes raised by sediment, so that the river is here unable to carry on all its load, and natural embankments called levées are deposited at the sides. In times of flood the river overflows its embankment and deposits alluvium (mud and sand chiefly) on the surrounding plain. The natural embankment is often strengthened by artificial levées. The raising of a bed of a river by deposition in a flood plain, or in the delta formed at its mouth, causes the bed of some of these rivers to be higher than the plains along the sides. Flood plains and deltas are very fertile, and form suitable places for settlement, so that some of these plains and deltas are amongst the most densely populated parts of the world. We may instance those of the Nile, of the Ganges, the Yangtse Kiang, in China, and the Mississippi.

Flora (Lat. *flos, floris*, a flower). The name given to the entire vegetation of a given area or epoch.

Fluviatile (Lat. *fluvius*, a river). The name applied to the deposit formed in a river, or to the animals and plants found there.

Fossil (Lat. *fossus*, dug). The name first given to anything dug out of the ground; now restricted to the remains or traces of remains of animals and plants found in the rocks of the earth.

Fossiliferous (Lat. *fossus*, and *fero*, I carry). Applied to rocks bearing or containing fossils or organic remains.

Freshet. The flood of a small stream or river, due to heavy rains or melted snow.

Fringing Reefs. The ridges of coral rock which fringe or skirt the shore. (*See* 'Coral Reefs.')

Fumarole. A hole or vent in a volcanic district from which gases or fumes arise.

Geyser. The name given to the hot springs which throw water at regular or irregular intervals into the air. The best-known geysers are those of Iceland and the Yellowstone Park, in the United States. Around the orifice of the geyser is deposited a siliceous rock called 'sinter,' or 'geyserite,' the deposit being aided by algæ living in the water.

Ghauts, or **Ghats.** An Indian term to denote originally the passes between mountains, but its meaning has become extended, until

it is now used to denote the mountains themselves ; *e.g.* the Eastern Ghauts, the Western Ghauts, ranges of hills running down the east and west coasts of India.

Glacier (Lat. *glacies*, ice). A stream of ice filling up a mountain valley, and derived from a snow-field above. (*See* figs. 61 and 118.)

Glacière. An ice-cave in which the ice, owing to the cold winter air lodging in the cavern, is not wholly melted even during the summer.

Gneiss. A rock containing the same mineral elements as granite, viz. quartz, felspar, and mica, but arranged in bands or layers.

Gnomon. A vertical pillar or obelisk used for astronomical purposes ; also the projection piece on a sundial.

Gorge. A narrow rocky valley or ravine with steep sides.

Graded Rivers. A river cannot wear down its course below a certain limit called its *base-level*, the sea being the permanent base-level. The lowest slope over which a stream can cut its channel and carry its load of sediment is called the *grade* of a stream. The grade line is a curve rising from the base-level at the mouth to the height at which the slope gives the water sufficient velocity to carry the load of waste it receives from the head waters and the side streams without either deepening or building up its bed. When such a slope is attained the river is said to be graded. All streams erode their beds towards grade slope ; below this some of their sediment is deposited on the bed, though vast quantities of rock waste, both in suspension and in solution, are still carried to sea by the great rivers.

Granite (Lat. *granum*, a grain). An igneous rock containing the three minerals, quartz, felspar, and mica, arranged so as to form a granular crystalline compound.

Graphite (Gk. *grapho*, I write), also known as 'plumbago,' or 'black-lead.' A form of nearly pure carbon, containing no lead whatever, which is found in Siberia and Ceylon, and is largely used for making lead pencils.

Gravel. The name applied to the pebbles and water-worn fragments of rocks.

Gravity, or **Gravitation** (Lat. *gravis*, heavy), is generally used to denote the attractive force with which the earth attracts all bodies, and so causes them to have weight. More generally, the *Law of Gravitation* states that 'Every particle of matter in the universe attracts every other with a force which varies directly as their masses and inversely as the square of the distance between them.' *Specific Gravity* is the ratio expressing the relation between the weight of a substance and the weight of an equal volume of pure water.

Great Circle Sailing. The shortest distance between two points on a globe or sphere is along the arc of a great circle, *i.e.* a circle the plane of which divides the sphere into two equal hemispheres. On a globe the meridians running directly north and south through the poles are great circles. All the parallels of latitude, except the equator, are small circles. Hence the distance between two places as measured in the compass direction is only the shortest distance between them when passing due north or south, or due east and west, along the equator. In other cases the shortest distance will be found by passing along the arc of a great circle passing through the places. Thus San Francisco is 2° north of east of Yokohama (lat. 35° 30′ N.). A piece of string running along the compass route between these two places on a globe will

be found to give a longer distance than if the string is allowed to fall on a great circle between the two places as indicated by the curve on the map on page 154. On a map on Mercator's projection all the points on the map correspond with the compass bearings, so that such a map is of great use to a navigator who wishes to sail according to the compass. If a vessel leaves San Francisco and sails 2° south of west it will arrive at Yokohama. But a steamer often wishes to take the shortest route. In this case the great circle between the two points is calculated, and the steamer would sail first north of west, and finally south of west, and the saving in the case given would amount to about 100 miles. Other great circle courses are shown on the map referred to, and it is seen that for places much east or west of each other the compass bearing route is not the shortest except at the equator. The saving is greatest in high latitudes.

Habitat (Lat. *habitat*, it dwells). The area or region where an animal or plant lives and grows.

Hail. Hail consists of pellets of ice of various shapes formed in the colder regions of the atmosphere. The larger masses often have concentric layers round a nucleus.

Herbivorous (Lat. *herba*, grass; and *voro*, I devour). Applied to animals that live on a vegetable diet; opposed to carnivorous.

Hoar-Frost, or **Rime,** is the frozen aqueous vapour of the atmosphere deposited on various substances.

Horizon (Gk. *horizo*, I limit). The circle which bounds that part of the earth's surface visible to a spectator from a given point is called the horizon, and at sea is perfectly horizontal. This horizontal circle is sometimes called the *visible* or *apparent* horizon, to distinguish it from the *celestial* or *astronomical* horizon, whose plane passes through the centre of the earth at a distance of 90 degrees from the place of observation. Half the heavenly bodies are above this horizon at any one time.

Horse-Latitudes. Two high-pressure belts over the Oceans with frequent Calms between the regions of the Trade Winds and the south-westerly and north-westerly variable winds of higher latitudes.

Humidity. Humidity is the term applied to the water vapour present in the air (Par. 13). The amount varies very much in different places, and even in the same place at different times, for the warmer the air is the more moisture can it contain. The actual amount of water vapour in a given volume of air expressed in ounces or pounds is called the *absolute humidity* of the air. It varies from 1 grain to 22 grains per cubic foot. But the important point connected with the vapour of the air is what is called its *relative humidity*. This is defined as 'the *percentage* of water vapour contained in the air compared with the amount which the air at that temperature could contain if it were *saturated*.' If we say that the air at a certain time has a relative humidity of 50, we mean that it contains only 50 per cent. of the water vapour that it could contain at the temperature at that time. Such air would feel 'dry.' A humidity near 65 per cent. is one that is wholesome and pleasant. Air with a percentage humidity over 90 is 'moist' or 'damp,' as it is nearly saturated at that temperature, and not because of the absolute quantity it contains. During the higher temperatures of summer there is often a greater absolute humidity

than during a winter day, though the relative humidity of the winter day may be much higher than that of the summer day. The relative humidity of the air is an important factor in climate. as both great heat and great cold can be borne better when the air is nearly 'dry.' We can see from what has been said that a quantity of air that is nearly saturated at 50° F. becomes relatively dry at a temperature of 70° F., and conversely that air which is nearly saturated at 70° will be obliged to give up some of its water vapour if the temperature falls to 60°. This has an important bearing on the formation of dew, cloud and rain. The temperature of the air at which the moisture present just saturates it is called the *dew-point*, for below this precipitation of the moisture begins. Instruments for finding the relative humidity of the atmosphere are called *hygrometers*. The principle of these instruments is first to find the dew-point, and then to calculate the relative humidity. In Mason's Hygrometer we have two similar thermometers placed side by side on a stand (fig. 22). One of these has its bulb freely exposed to the air, the 'dry-bulb thermometer'; the other, called the 'wet-bulb thermometer,' has its bulb kept moist by being connected through cotton wick with a vessel of water. Evaporation of moisture from the wet bulb reduces the temperature of this thermometer, and the drier the air the more rapid the evaporation, and the lower the temperature it shows compared with the 'dry-bulb' thermometer. From the difference of reading the two thermometers the dew-point can be determined for the air temperature shown by tables, and when the dew-point is found the relative humidity can be calculated.

Hurricane. A violent whirling storm of wind (Par. 23).

Hygrometer (Gk. *hugros*, moisture; and *metron*, a measure). An instrument for determining the amount of water-vapour present in the air. (*See* fig. 22.) The nearer the temperature of the wet bulb thermometer is to that of the dry bulb thermometer, the nearer the air is to saturation.

Iceberg (Ger. *eis*, ice; *berg*, mountain). A huge mass of ice broken off from a large Arctic or Antarctic glacier, which floats away, carrying with it boulders and other débris from the land. It gradually melts as it proceeds southwards, depositing the boulders at the bottom of the sea.

Ice-cap. The permanent covering of ice, formed of compacted snow, that rests on the surface of the land in very cold climates. Greenland is covered with an ice-cap, squeezing out its borders in the form of glaciers to the sea. Portions of these glaciers break off and give rise to *icebergs*.

Ice-floe. The name given to the smaller masses of ice which are found in Polar seas, but differ from icebergs in that they are formed of marine ice.

Ice-foot. The cake of ice formed along the edge of the shore by the freezing of the sea-water.

Ice-pack consists of broken ice-floes forced together by the wind and currents.

Igneous (Lat. *ignis*, fire). The term applied to rocks that have been produced through the agency of fire or by volcanic forces; used in contradistinction with aqueous rocks, that have been formed by the action of water.

Indigenous (Lat. *native*). Applied to the plants and animals native to a country ; opposed to exotic, or introduced from without.

Island. A portion of land entirely surrounded by water. A group or cluster of islands forms an *archipelago.*

Isotherm (Gk. *isos*, equal ; *therme*, heat). An isotherm is a line connecting places on the earth's surface which have the same temperature. Such lines are found drawn on maps for various periods, as a month, six months, etc., but the term isotherm, when not limited, is understood to give the mean temperature of the year at the level of the sea. Winter isotherms passing through places having the same mean winter temperature are termed **isocheimonal** lines (Gk. *cheima*, winter) ; summer isotherms passing through places having the same mean summer temperature are termed **isotheral** lines (Gk. *theros*, summer). (*See* Maps.) These words are, however, rarely used.

Isthmus (Gk.). A narrow strip of land bordered by water and connecting two larger bodies of land. That of Suez and that of Panama, or Darien, are the most important.

Karroo. Karroos are large tracts of clayey tableland in South Africa which rise terrace-like towards the interior. In the wet season they are covered with grasses and flowers, but in the dry season the land becomes parched and nearly barren. The Great

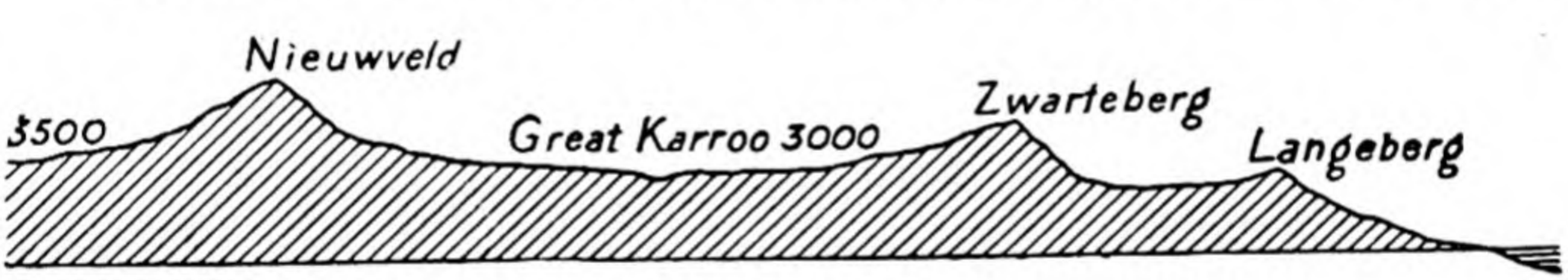


FIG. 126.

Karroo, in Cape Province, is the tableland between the Nieuwveld Mountains and the Zwarteberg.

Kuro Siwo, or Kuro Shiwo (Jap. *black current*). The warm current, or Gulf Stream, of the Pacific, which flows along the coast of Japan (*see* Par. 40). So called from the dark colour of its waters.

Lacustrine (Lat. *lacus*, a lake). Of or belonging to a lake ; *e.g.*, lacustrine deposits are deposits formed at the bottom of lakes, and lacustrine deltas are deltas formed where a stream enters a lake.

Lagoon (Lat. *lacuna*, a ditch or lake). A shallow lake bordering on the sea, and whose water is usually brackish ; also used to denote the small lake enclosed by an atoll, or circular coral reef.

Lake (Lat. *lacus*, a lake). A body of water surrounded by land, and not forming part of the sea. They are formed by streams flowing into a depression in the land, and hence the water of a lake is usually fresh. In Scotland and Ireland they are called **lochs.**

Landes (Fr.). A lande is an uncultivated plain covered with heath, broom, and ferns. 'The Landes' is a name given to the region lying along the coast between the Pyrenees and the estuary of the Gironde, in Southern France. They are dry in summer and marshy in winter, and have now been extensively afforested.

Landslip, or **Landslide.** The falling or sliding down of a mass of soil or rock on a mountain side, often due to the undermining action of water.

Lapilli (Lat. *lapillus*, a little stone). Small fragmentary materials ejected from a volcano in eruption, varying in size from a pea to a walnut, and often so cellular—*i.e.* full of small holes—that they will float on water.

Latitude (Lat. *latitudo*, breadth, width). The distance of a place north or south of the equator measured in degrees along a meridian.

Latitude (Determination of). Latitude is angular distance north or south of the equator measured on an arc of a meridian. The portion of this arc between a place and the equator, or the angle that this portion of arc subtends at the earth's centre, gives the measure of the latitude of the place in degrees. To find the latitude of a place one of several methods may be employed. (*a*) The simplest method of finding the latitude of a place is to find the altitude of the pole star, for this angular measurement is equal to the observer's latitude. At the equator the pole star is on the horizon (Par. 91, fig. 102), and as we pass northwards the altitude of the pole star increases with the increase of latitude, so that at the pole the pole star is in the zenith. Thus the latitude of a place is given directly by the altitude of the pole star above the horizon. Where great accuracy is required the true celestial pole must be found—the point midway between the lowest and highest position of the pole star (fig. 101), or the mean of the altitudes of the upper and lower transits of any circumpolar star, gives the altitude of the celestial pole. (*b*) The latitude of a place can be found after determining *the sun's meridian altitude*; for on subtracting the noon-day altitude of the sun from 90° we get the sun's zenith distance, which on being added to or subtracted from the sun's declination (the angular distance from the equator) gives the latitude of a place. This second method of finding the latitude of a place depends on the fact that *latitude is equal to the angle between the zenith and the celestial equator.* This may be readily seen from fig. 104 or from fig. 127. This last is a simple figure of the celestial sphere at a latitude 27° N. The line H R represents the plane of the horizon, an observer being at the centre O. N is the north celestial pole at an altitude of 27°, N O half the celestial axis; E Q the celestial equator at right angles to N O, so that arc N E = 90°. The arc Z E is evidently equal to arc H N, *i.e.* the angle between the zenith and celestial equator. S and S^1 are positions of the sun at different dates with different declinations. We proceed as follows:—Find the altitude of the sun at noon as it crosses the meridian; subtract this altitude from 90° and we get the sun's zenith distance. The sun's zenith distance plus the sun's declination when north of the equator, or minus when south of the equator, gives the zenith distance of the celestial equator, and thus is equal to the latitude, as just shown from fig. 127. At the equinoxes the sun's declination is zero. For example: A captain

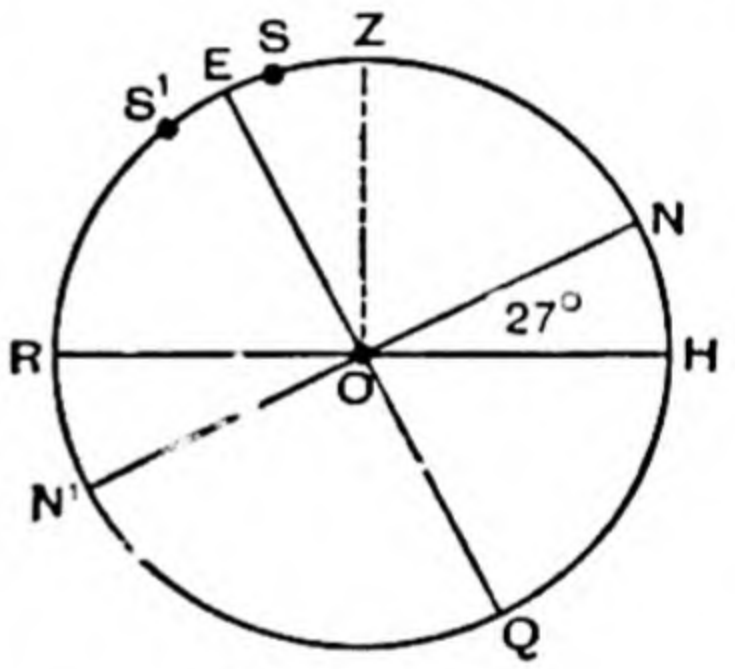


FIG. 127.

in the northern hemisphere finds the sun's meridian altitude on a certain date to be 72°. The sun's declination for that day is 9° north; find the latitude. Here 90° − 72° = 18° sun's zenith distance; 18° + 9° = 27°, the latitude N. Again: On a certain day the sun's altitude in the northern hemisphere is found to be 50½°; the sun's declination on that day was 12½° S; find the latitude. There 90° − 50½ = 39½° sun's zenith distance, and 39½ − 12½ = 27° N. latitude. Both these cases are illustrated in fig. 127. Others may be readily solved for other northern latitudes. So also for the southern hemisphere on producing N O to the south celestial pole N¹ and inverting the figure.

Lava (Lat. *lavare*, to wash). The molten matter which issues from a volcano during an eruption, and then gradually cools, forming various kinds of igneous rocks.

Leeward (Old English, *lee*, shelter). Towards the lee, or that part towards which the wind blows. The side of a ship or hill sheltered from the wind is the *leeward* side, whilst that exposed to the wind is the *windward* side.

Levée (Fr. *lever*, to raise). The embankment raised to keep a river within its proper channel; *e.g.*, the levées of the Mississippi.

Licks. Swampy places near salt springs where salt is deposited; so called because animals are said to come and lick the soil for the sake of the salt.

Ligneous (Lat. *ligneus*, wooden). Consisting of or resembling wood; having a woody fibre or texture.

Lignite (Lat. *lignum*, wood). The name given to imperfectly formed coal in which the original form of the wood can be easily recognised; often called *brown coal* from its colour. It contains more oxygen and less carbon than true coal, and in its chemical composition seems to stand midway between coal and wood.

Limestone. A rock formed usually of the remains of sea-shells, corals, etc. It is a form of calcium carbonate, and when heated strongly it gives off carbon dioxide (carbonic acid), and leaves *quicklime*, or *lime*. It is insoluble in pure water, but dissolves to some extent in water charged with carbonic acid.

Littoral (Lat. *litus*, *litoris*, the seashore). Of or belonging to the shore of the sea or great lake; opposed to *pelagic*, belonging to the deep sea.

Llanos (Spanish). The level treeless plains surrounding the lower and middle course of the Orinoco, in South America. They have a sparse vegetation, except during the rainy season, when they afford splendid pasturage for large herds of cattle.

Loam. A soil consisting of a natural mixture of clay and sand.

Loess. Used originally to denote a certain fine loamy deposit in the Rhine Valley, but now used for any similar deposit. In Northern China loess covers a vast area, and is of great thickness. Most loess is of aeolian origin, *i.e.* borne and deposited by the wind.

Longitude (Lat. *longitudo*, length). The distance of a place measured in degrees east or west of a given meridian is called its longitude. In England, and often in the United States, the meridian passing through Greenwich is the first or prime meridian, marked 0°, from which longitudes are measured, Other countries sometimes use their own prime meridian, though there is a general agreement to adopt that of Greenwich.

Longitude (Determination of). Longitude is angular distance east or

west of the zero or prime meridian—the meridian passing through Greenwich. Meridians, as explained in Par. 88, are great circles passing through both poles, and cutting the equator perpendicularly. They are so called because midday occurs at the same moment at every place situated on that half of a meridian circle turned to the sun. It is midnight to every place on the opposite half of a meridian circle. All places on the same half of a meridian circle have the same longitude, for the longitude of a place is measured from the zero meridian of Greenwich, east or west, whichever is nearer. The meridian 180° E. and 180° W. is the same semicircle on the opposite side of the globe to the zero meridian of Greenwich. Longitude being measured in degrees east or west, either on the equator or on any parallel of latitude, the length in miles of a degree of longitude gets less as we pass

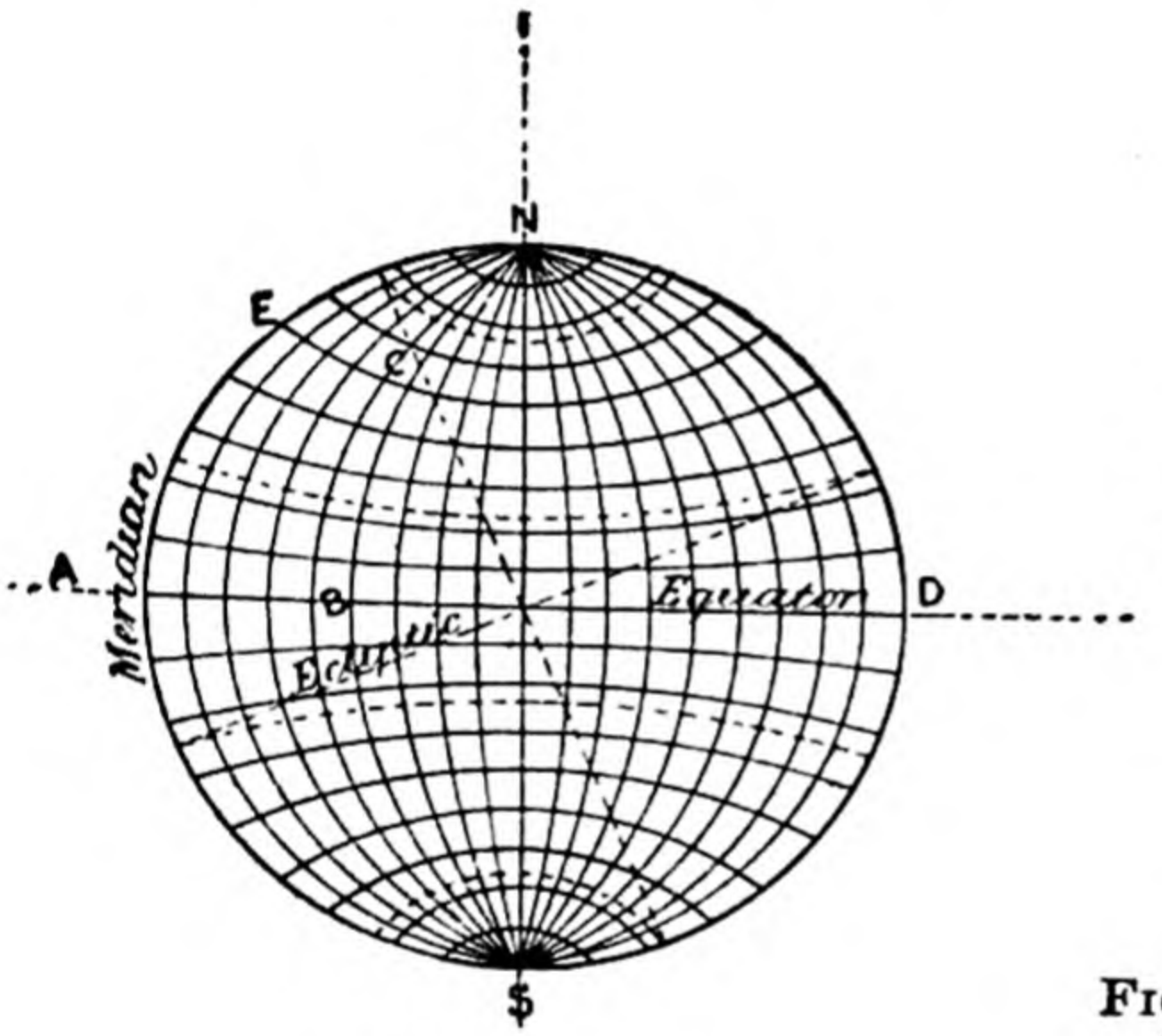


FIG. 128.

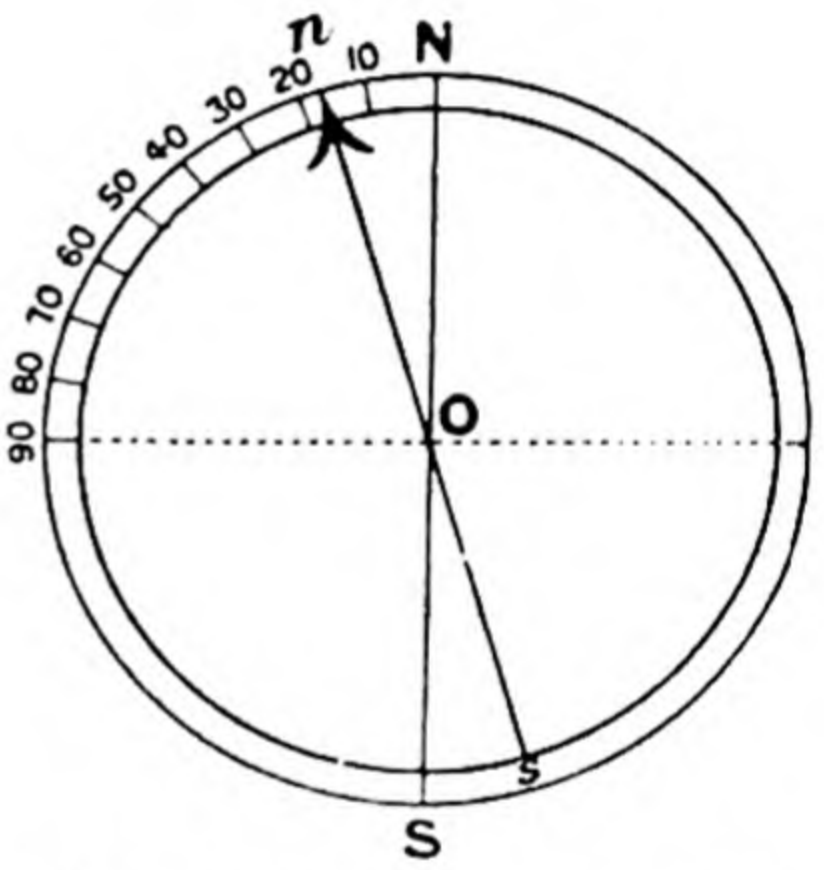


FIG. 129.—DIAGRAM SHOWING VARIATION OF COMPASS NEEDLE FROM TRUE NORTH.

from the equator, as the degrees become the 360th part of circles (parallels of latitude) that diminish in linear size as they get nearer the poles. The relation of longitude to time is such that 1 degree of longitude corresponds to 4 minutes of time, for as the earth rotates on its axis once in 24 hours, it describes 360 degrees in 24 hours, or 360 ÷ 24 = 15 degrees in 1 hour, or 60 mins. ÷ 15 = 1 degree in 4 mins. We can, therefore, understand that the difference between the 'local times' at any two places will give the difference of their longitudes, that the time on an eastern meridian is earlier than on a western meridian, and *vice versâ*. On this relation of longitude to time is based the method of finding the longitude of any place, supposing we have a chronometer giving the exact Greenwich time. The first thing to be done, then, is to determine the local time, *i.e.* the time at the place of observation. This is usually done by observing the meridian

passage of the sun by means of a sextant, so as to notice the instant when its altitude is greatest. The difference between the local noon thus found and the time shown by the chronometer will give us the longitude, for, as just seen, every 4 minutes difference in time corresponds to 1 degree—east if local noon is in advance of chronometer, west if behind the chronometer. For example, an observer on a ship notes that when the sun is at its meridian altitude, the chronometer shows 9 hrs. 10 min. A.M. His local time is therefore 2 hrs. 50 min. or 170 min. in advance of Greenwich time. Since 4 min. corresponds to a difference of 1 degree, 170 min. gives a difference of $170 \div 4 = 42\frac{1}{2}°$. His longitude, therefore, is 42° 30′ E. The difference in longitude of two places explains the fact that a telegram sent westwards may appear to arrive earlier in the day than the time at which it was sent out. A time signal sent as a telegram from London at 11.45 would arrive, if it went instantaneously, in New York 11 minutes before 7 in the morning of the same day. How is this? What is the longitude of New York: Ans. 74° W. (*See also* Quest. 160 with answer.)

Magnetic North or South. The position which a horizontal magnetic needle takes up when freely suspended gives the magnetic meridian at that place, and thus the magnetic north and south. This may or may not coincide with the geographical meridian as shown by the sun's shadow at noon, the angle between them being known as the 'variation east or west' of the magnetic north. In England the magnetic needle points about $17\frac{1}{2}°$ west of north. (*See* 'Cardinal Points.')

Marine (Lat. *mare*, the sea). Of or belonging to the sea.

Meridian (Lat. *meridies*, midday). A great circle of the earth passing through the poles and cutting the equator at right angles. Corresponding circles in the sky are sometimes called **celestial meridians,** and the sun or other heavenly body is at its highest point on any day when it transits, or crosses the meridian (*see* Longitude).

Mesa (Lat. *mensa*, a table). A Spanish word used for tableland in the south-west of the United States and Mexico.

Metamorphic (Gk. *meta*, change; and *morphe*, form). The term applied to rocks which, owing to the action of heat, pressure, and other agencies, have become changed in form and structure.

Mile. The ordinary statute mile is 1,760 yards, or 5,280 feet; a geographical mile is the 60th part of a degree of latitude, and is nearly the same as the nautical mile, or knot, 6,080 feet. The geographical and nautical mile is thus about one-sixth more than the statute mile.

Mineral (Lat. *mina*, a mine). A mineral is a naturally formed inorganic substance which has a constant chemical composition and constant physical properties.

Mist. The name given to atmospheric vapour which has become visible owing to a reduction of temperature. Condensation of water-vapour from the atmosphere takes place around dust particles floating in the air when any cause reduces the temperature. A fog is similar to a mist, but the particles of moisture are rather smaller.

Molecule (Lat. *molecula*, dim. of *moles*, a mass). The smallest portion of matter that can exist by itself.

Monsoon (Arabic, a season). The periodical or seasonal winds which blow over the Indian Ocean and the adjacent countries. The

north-east monsoon blows from October to April, and the south-west monsoon the remaining part of the year.

Moraine. The rocky detritus which falls from a mountain side on a glacier. In the higher valleys there are only two moraines (*lateral moraines*), one on each side; but where two glaciers unite their nearest moraines merge into one, forming a *medial*, or central, moraine. At the point where the glacier becomes all melted this rocky material accumulates, forming the *terminal moraine*, and beneath the ice is a mass of material termed the *ground moraine*. (*See* figs. 118, 130.)

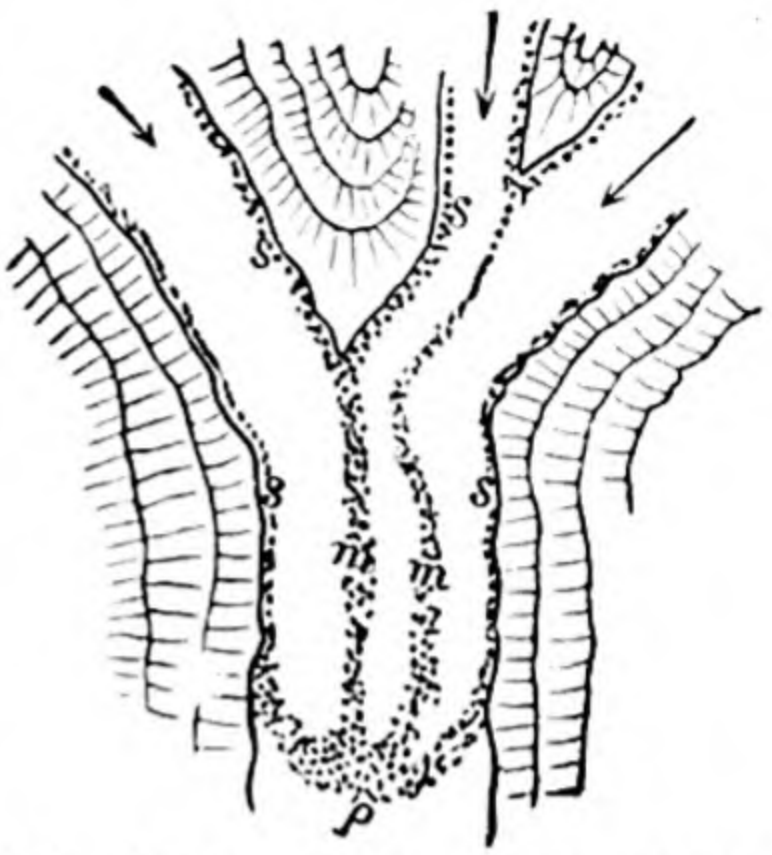


FIG. 130.—PLAN SHOWING POSITION OF MORAINES.

s, *s*, lateral moraines;
m, *m*, middle moraines;
p, terminal moraines.

Morass. A low, moist, swampy region where there is little or no drainage.

Mountain. An elevation of land rising more or less abruptly above the surrounding district to a considerable height (above 2,000 feet). Elevations of less than that height are usually called **hills.**

Mud. Moist, soft, earthy matter which, when hardened and compressed, forms **shale.**

Nadir. That point of the heavens which is vertically beneath any station upon the earth. It is diametrically opposed to the **zenith,** or point directly overhead.

Naze, or **Ness.** A promontory or point of land running into the sea; *e.g.* Dungeness, The Naze, etc.

Neap Tides (A.-S. *nëp*, scant, lacking). The tides halfway between spring tides, which have the least difference between flood and ebb.

Nevé, or **Firn.** The collected snow on the higher slopes of mountains, which, being compressed in the valleys, forms a glacier.

Nitrogen. The name of the gas which constitutes nearly four-fifths of the atmosphere.

Nodule (Lat. *nodulus*, a little knot). A rounded mineral mass which has collected round some nucleus; *e.g.* flint nodules are often found in chalk.

Normal (Lat. *norma*, a rule). According to rule; regular or natural.

Nucleus (Lat. *nucleus*, a little nut or kernel). A central mass round which matter has collected.

Oasis. A green and fertile spot in a desert, caused by the presence of a spring.

Oblate (Lat. *oblatus*, spread out). Applied to bodies which are otherwise spherical, but slightly flattened at the poles like an orange. The earth is an oblate spheroid, its polar diameter being less than the equatorial diameter by 27 miles.

Obliquity of Ecliptic. The angle which the plane of the ecliptic makes with the plane of the equator.

Ooze, or **Oaze** (A.-S., *wase*, mud). Soft mud or slime, largely composed of calcium carbonate, found covering extensive areas of the ocean floor. (*See* Par. 35.)

Orbit (Lat. *orbis*, a circle, ring). The path traced out by a planet or comet in its revolution round the sun. The orbits of the plane are elliptical, having the sun at one focus of the ellipse.

Ore. A mineral from which a metal can be extracted. If the metal itself is found pure, it is said to be *native*.

Organic (Gk. *organon*, an organ). Produced by the organs of animals and plants; produced by a living organism, and distinguished from minerals, which are called inorganic.

Oxbow. An oxbow is the cut-off bend of a river. (*See* 'Flood-plain.')

Oxygen (Gk. *oxus*, sharp, acid; *gennao*, to produce). The important gas which constitutes one-fifth of the atmosphere, and upon which all animal life depends. It is a constituent of most acids, hence its name.

Pampas. The vast treeless plains in the Argentine Republic, in South America. Though treeless, they were covered with grass, forming part of the Temperate Grasslands. They are now largely cultivated.

Pampero. A cold, south-westerly wind that sometimes blows for a short period over the pampas.

Pass (Lat. *passus*, a step). In geography, a depression or gap in a mountain range through which travellers may pass from one side to the other. A long narrow pass is sometimes termed a **defile.**

Peat is the brownish black, compressed mass of partially decomposed vegetable matter which is found in the bogs and marshes of the British Isles; *e.g.* in the West of Ireland, in the Fen districts of England, in the swampy districts of Northern Europe, and various parts of the United States.

Pelagic (Gk. *pelagos*, the deep sea). Of or belonging to the deep sea; used in contradistinction with littoral.

Peninsula (Lat. *pene*, almost, and *insula*, an island). A piece of land almost surrounded by water, and only connected to the mainland by an isthmus.

Percolate (Lat. *per*, through; *colare*, to filter, strain). To trickle through; *e.g.* water is said to percolate through the interstices or the pores of certain rocks.

Perigee (Gk. *peri*, near, and *ge*, the earth). The moon is said to be in perigee when it is at that point of its orbit which is nearest to the earth. When it is at the point of its orbit which is farthest from the earth it is said to be in **apogee** (Gk. *apo*, away from).

Permeable (Lat. *permeo*, I pass through). Applied to rocks and other substances that allow water or any other liquid to pass through them.

Petrify (Gk. *petra*, a rock). To turn or convert into stone. Vegetable and animal tissues sometimes become impregnated with water containing mineral matter in solution, and as the tissues die and decay this mineral matter is deposited, takes the place and assumes the original shape of the tissue. This process is known as **petrifaction,** and springs charged with such mineral matter are hence called *petrifying springs.*

Phase (Gk. *phasis*, an appearance). The different appearances presented to the earth by the moon, or by one of the planets, are termed its phases.

Phenomenon, pl. **Phenomena** (Gk. *phainomai*, I appear). Any natural appearance or fact which has been directly observed by the senses.

Planetary Winds. The term *planetary winds* is applied to the steady trade winds and the prevailing westerly winds of both hemispheres, since they belong to the earth as a whole and result from the distribution of the sun's heat according to latitude combined with the daily rotation of the earth on its axis, and since they may be assumed to exist on other rotating planets that have an atmosphere. An account of these winds is given in Chap. III.

Plateau (Fr. *plateau*, a platform). An elevated and comparatively flat surface of land, often bordered by mountain ranges; a raised tableland of considerable extent; *e.g.* the Plateau of Tibet in

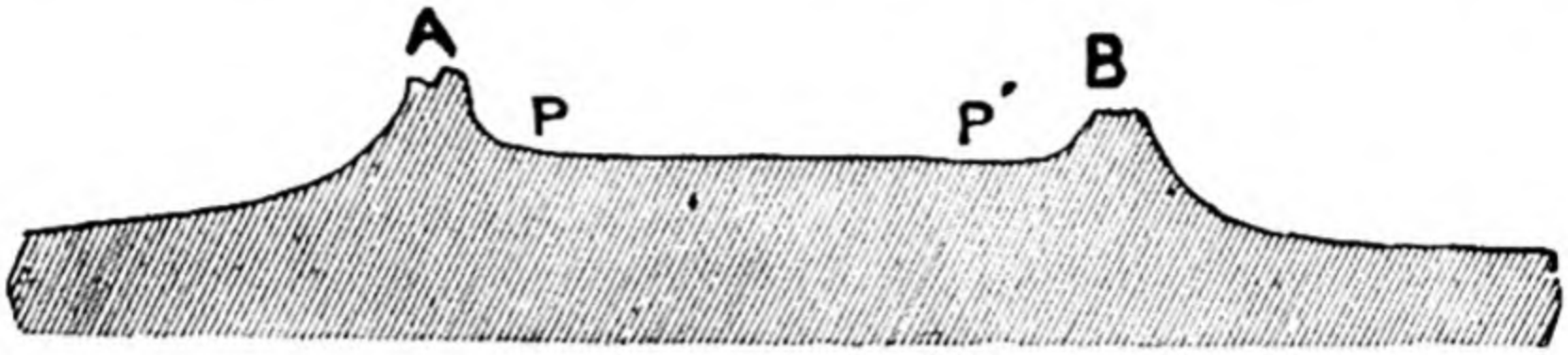


FIG. 131.

P, P′ Tableland bordered by Mountain Chains, A, B.

Central Asia, the Bolivian Plateau, etc. Such tablelands are usually dry, owing to the winds that reach them being deprived of moisture.

Plumbago (Lat. *plumbum*, lead), or black lead, is another name for graphite, one of the natural forms of carbon, and containing no lead whatever.

Plutonic (Lat. *Pluto*, the god of the lower world). Igneous rocks are divided into two classes, plutonic rocks and volcanic rocks. Plutonic rocks are such igneous rocks as have been formed under conditions of depth and pressure and have cooled slowly, thus acquiring a more or less crystalline structure. Volcanic rocks are igneous rocks formed near the surface of the crust of the earth.

Pluvial (Lat. *pluvia*, rain). Of or pertaining to rain; rainy. In geology, the particular kind of denudation effected by rain is called pluvial denudation.

Polders (Dutch). Tracts of marshy land in the Netherlands which have been reclaimed by drainage and brought under cultivation.

Pole Star. The star Polaris, situated near the north pole of the heavens. Around it the other stars appear to rotate, in consequence of the earth's daily rotation. The altitude of the Pole Star is always equal to the latitude of the place of observation. At the equator the Pole Star is on the horizon. Passing northwards, we find its height above the horizon to increase one degree (1°) for every 69½ miles from the equator—a proof of the spherical form and size of the earth. (*See* fig. 101.)

Poles (Gk. *polos*, a pivot). The two points on the earth's surface at the ends of the axis of rotation are called the *terrestrial poles*. The axis produced meets the heavens at the *celestial poles*. The one which is on the left when one looks in the direction of the earth's surface motion (*i.e.* from west to east) is the *North Pole*, the other the *South Pole*.

Pot-holes. A pot-hole is a rounded cavity in the rocky bed of a stream or glacier formed by eddies of water carrying round pebbles and sand.

Prairie (Lat. *pratum*, a meadow). The level or slightly undulating grassy plains in the centre and south of North America. They are treeless and form part of the great mid-latitude grasslands of the world. They are now largely cultivated.

Precipitation (Lat. *præcipitare*, to cast down). This term is often applied to the water condensed from the air and deposited as rain, snow or hail, *e.g.* ascending currents of air are cooled and are therefore associated with condensation and **precipitation** (*i.e.* fall of rain, snow or hail). Dew is also a form of precipitation. (*See* Pars 25, 28, and 30, for the account of precipitation.)

Pumice, an ashy grey, rough lava having a loose spongy structure, and either ejected from a volcano or found on the surface of a lava stream. Its pores were caused by escaping gases or steam, and it will float on water, owing to these cavities being filled with air, for a considerable time, until it becomes waterlogged and sinks. Powdered pumice quickly sinks in water, its specific gravity being 2·5.

Quadrumana (Lat. *quatuor*, four ; *manus*, a hand). A term applied to apes, monkeys and lemurs (the lowest monkeys) because they can use all their limbs as hands.

Quartz, or rock crystal, is one of the commonest rock-forming minerals, forming one of the constituents of granite. It is pure silica (SiO_2), and when crystallised and the crystals complete they consist of six-sided prisms, terminated at each end by six-sided pyramids. Chalcedony, agate, amethyst, flint, etc., are forms of impure silica, coloured more or less with metallic oxides, and all consisting chiefly of silica.

Quicklime. A white amorphous, infusible solid, obtained by strongly heating chalk, limestone, or any other substance containing calcium carbonate. When water is added to it a violent chemical reaction goes on, with the production of a large amount of heat and the formation of a new solid, called *slaked lime*.

Rainbow. A rainbow consists of a series of circular bands coloured with the tints of the solar spectrum. It is formed in that part of the sky *opposite* the shining sun when rain is falling. It is caused by the refraction, reflection and dispersion of the sun's rays in the raindrops. The outside of the rainbow arc is red, and then come orange, blue, green, indigo, and violet, the last forming the inner edge of the bow. The bow seen is part of a circle, the other part being below the horizon. A bow is not visible when the sun's altitude is above 42°, and the nearer the sun is to the horizon the more of the bow is there visible. With the sun on the horizon the part of the bow seen is a semicircle. Sometimes an outer and fainter *secondary* rainbow is seen, in which the order of colours in the primary bow is reversed.

Rain Gauge and Measurement of Rainfall. A rain-gauge is an instrument for measuring the rainfall at any place, the term 'rainfall' or 'precipitation' including rain, snow and sleet. By an 'inch of rain' is meant rain to the depth of an inch upon any surface ; but as measurements are taken daily, arrangements must be made for measuring small quantities, for small fractions of an inch of rain could not well be measured directly. Various forms of rain-gauge are in use. To measure a small quantity caught in a cylindrical vessel of a certain area it may be transferred to another vessel of smaller area, say, one-tenth the area. Thus a tenth of an inch caught in the larger vessel would give one inch in the

smaller vessel, and this inch could be divided into ten parts, so that we could thus measure hundredths of an inch. A *standard rain-gauge* consists of a funnel emptying into a can, funnel and can being placed inside a circular copper vessel, as shown in fig. 32. The diameter of the funnel is 8 inches, so that the area of its collecting surface is 50·26 square inches.[1] One inch of rainfall—*i.e.* rain one inch deep—would therefore deposit in this rain-gauge 50·26 cubic inches of rain; half an inch of rainfall would deposit 25·13 cubic inches of rain. Now 25·13 cubic inches = 14¾ fluid ozs. If, then, 14¾ fluid ozs. be poured into a measuring glass of uniform diameter, a line at this level will represent half an inch of rain. On dividing the vessel below the line into 50 equal parts, each of these will represent $\frac{1}{100}$th inch of rainfall. By emptying the can into the measuring glass, graduated as above, at a certain time (9 A.M.) each day, the amount of rainfall for one day can be obtained. Of course, on very wet days the can might need emptying more than once, though a rainfall of 0·1 is considered a rainy day in Britain. To avoid errors in estimating rainfall the rain-gauge should be placed in an exposed situation about one foot above the ground. Its rim should be kept horizontal, and measurements should be made at least daily at a fixed time. Were more time to elapse between each measurement, the loss by evaporation would lower the quantity. In case of snowfall, the depth may be measured directly when it falls evenly. Ten inches of snow is reckoned as equal to one inch of rain, but there is some variation, owing to the snow crystals being more compacted at some times than at others. A more exact way, therefore, is to take the snow collected in the rain-gauge and melt it, to find the depth of rainfall it represents. By adding the daily amounts in a year at any place together, the total rainfall for that year at that place is obtained. By taking the total amounts of the annual rainfall for a number of years and dividing by that number, the 'average or mean rainfall' is ascertained. This is done at many places in Britain and other countries, and thus rainfall maps can be prepared.

Rainy and Dry Seasons. Near the thermal equator (Par. 20) the sun's heat causes great evaporation; the heated air of the surface expands and rises, and in doing so becomes cooler, so that its water vapour condenses into clouds and rain. There is, therefore, near the heat equator in the equatorial belt of calms a zone of almost constant heavy rains. In the torrid zone, outside this rainy belt, there is a rainy season when the sun is overhead, and a drier season after the sun has moved north or south. Since the sun is twice a year in the zenith between the tropics, there are near the equator two rainy seasons and two dry seasons, but only one near the northern and southern tropics themselves. Where the interval between the two zenith passages of the sun is short, the two rainy seasons merge into one longer one, as do also the two dry seasons. India has one rainy season when the south-west monsoon of the summer months, blowing from a warm sea, brings warm moist winds to be chilled by the land, especially the hills, and one dry season when the north-east monsoon of the winter months comes from the cold land in the north, has its temperature raised as it passes south, and therefore parts with no moisture (Par. 21). The rainfall of the countries bordering the Mediterranean has a seasonal

[1] The area of a circle = 3⅐ times the square of the radius.

character, for Eastern Spain, Italy, Greece and Asia Minor have a dry summer and get much rain in autumn and winter. In summer the trade-wind belt moves north, reaching the southern part of the Mediterranean ; and these north-east winds draw from above these countries, which thus pass into warmer regions. In the late autumn and winter, however, these countries come under the influence of the rain-bearing south-westerly winds. Wherever, in fact, the direction of the wind varies greatly with the season of the year, the rain will be unequally distributed during the months.

Rapid. A swift river current, more or less broken by obstruction of rock, produced by a rather sudden slope of the river bed.

Ravine. A long, deep hollow, with steep sides, worn by a stream or a torrent of water ; any deep, narrow gorge.

Reef. A low, narrow ridge of rocks, rising usually but a few feet above the surface of the sea or probably only at low tide. (*See* 'Coral Reefs.')

Regelation (Lat. *re*, again ; *gelo*, I freeze). Ice becomes liquid under pressure, and the water formed spreads over the surfaces pressed together. When the pressure is removed the water freezes again, and binds the masses together.

Relief. In geography relief refers to the elevation of the surface of any part of the earth above sea-level. It is often indicated on maps by colour, shading, or contour-lines. Vertical sections are

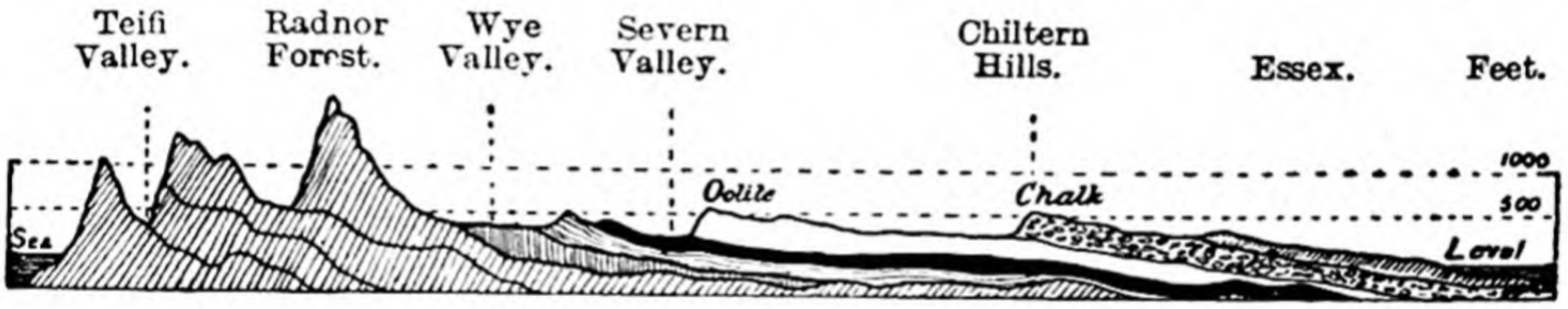


FIG. 132.—SECTION OF ENGLAND FROM SOUTH WALES TO ESSEX.

also made to indicate both relief and the nature of the rocks. The annexed figure shows a section through England from South Wales to Essex. Note the escarpments of the chalk and oolitic limestone strata.

River. A large, continuous stream of water flowing in a definite course or channel in the land. Looking towards the mouth, the bank on the right is the *right bank*, and that on the left the *left bank*.

River System. A principal river and all its affluents.

Roadstead, or **Roads.** An open and exposed anchorage near the shore, in which vessels may shelter when the wind is in the proper direction.

Roaring Forties. A belt of the ocean between 40° and 50° S., in which 'the brave west winds' blow regularly all the year round, thus enabling sailing vessels going to New Zealand by the Cape of Good Hope and returning by Cape Horn to make a quick passage.

Roche Moutonnée (Fr.). The name given to the rounded and polished surfaces of rock worn down and smoothed by glacier or ice action until they assume the rounded, smooth appearance of a sheep's back, and hence their name (sheep-rock).

Salses (Lat. *salsus*, salt). Eruptions of hot, acidulated mud from small orifices in volcanic districts, forced upwards by gases and steam.

Sand. The worn particles or detritus of previously existing rocks reduced to small grains. It usually contains a large amount of quartz, as this mineral undergoes little or no chemical decomposition. Sand, when consolidated by pressure or held together by some cement, forms the rock known as **Sandstone.**

Sargasso Sea. A region of the North Atlantic Ocean around which the Gulf Stream circulates, and so named because of the abundance in it of the sea-weed sargassum, which lives and floats in the open sea.

Saturated (Lat. *saturare*, to fill full). A fluid which holds in solution as much of any substance as it can dissolve is said to be saturated with it, though it may dissolve another substance ; *e.g.* a saturated salt solution will dissolve sugar. (*See* also Par. 13.)

Savannah, or **Savana.** Grassland with scattered trees.

Scoriae (Gk. *scoria*, refuse, scum), or cinders, is the name given to the rough, angular, cindery looking material sent out from a volcano, or forming the slag and scum on the surface of some lava streams.

Scree, or **Screes.** The pile of *débris*, consisting mainly of rocky fragments, found at the bottom of a cliff or steep hill, and due mainly to weathering of the rock ; also termed **talus.**

Sea-level. Heights and depths on the earth's surface are usually measured from what is called ' sea-level.' Owing to tides and other causes, the level of the sea is continually varying, but an average or ' mean sea-level ' is taken, and from this measurements are made. *Sea-level*, therefore, means *mean sea-level*. Even this varies somewhat at different places, so that each country takes some definite place at which the mean sea-level is calculated. On British Ordnance maps the datum level from which heights were reckoned was ' the mean sea-level at Liverpool,' though this is about 8 inches too high for the average level round Great Britain. On charts for navigation purposes the average level of low water at spring tides is taken as the datum level.

Sediment (Lat. *sedeo*, I sit). The matter which settles to the bottom of water or any other liquid ; hence *sedimentary rocks* are rocks that have been formed from detrital material—sand, mud, clay, etc.—that has been suspended in water and settled to the bottom.

Selvas, or **Silvas** (Lat. *silva*, a wood). The rank tropical forest plains forming the valley of the Amazon.

Shoal. A shallow place in the sea or other body of water ; a sandbank showing at low water.

Silex, or **Silica** (Lat. *silex*, flint). A white or colourless solid, extremely hard, insoluble in water, and almost infusible. It is one of the common rock-forming substances in the earth's crust. It is the basis of all the class of rocks known as silicates ; *e.g.* felspar is a compound of the oxides of potassium and aluminium combined with silica, etc.

Silt. A deposit of mud or fine soil from running or standing water which sometimes blocks up the entrance to harbours, estuaries, etc. ; a fine sediment, finer than sand but coarser than clay.

Simoom. An intensely hot, dry, whirling wind which sometimes blows in Arabia and Egypt from over the desert, raising clouds of sand. It appears suddenly, moving in a straight, narrow track, and has a most suffocating effect.

Sirocco. A hot, dry, dust-laden wind which sometimes blows from the high land of Africa to the coasts of Malta, Sicily, and Naples.

Snow-line. The snow-line, or limit of perpetual snow, is that line

below which the solar heat of summer is sufficient to melt all the snow that falls, but above which more snow falls than the heat of the summer can melt (*see* Par. 30).

Soil (Lat. *solum*, the ground). The superficial covering of the crust of the earth, in which plants grow; formed by the disintegration and decomposition of rocks, mixed with vegetable and organic matter (*see* fig. 133).

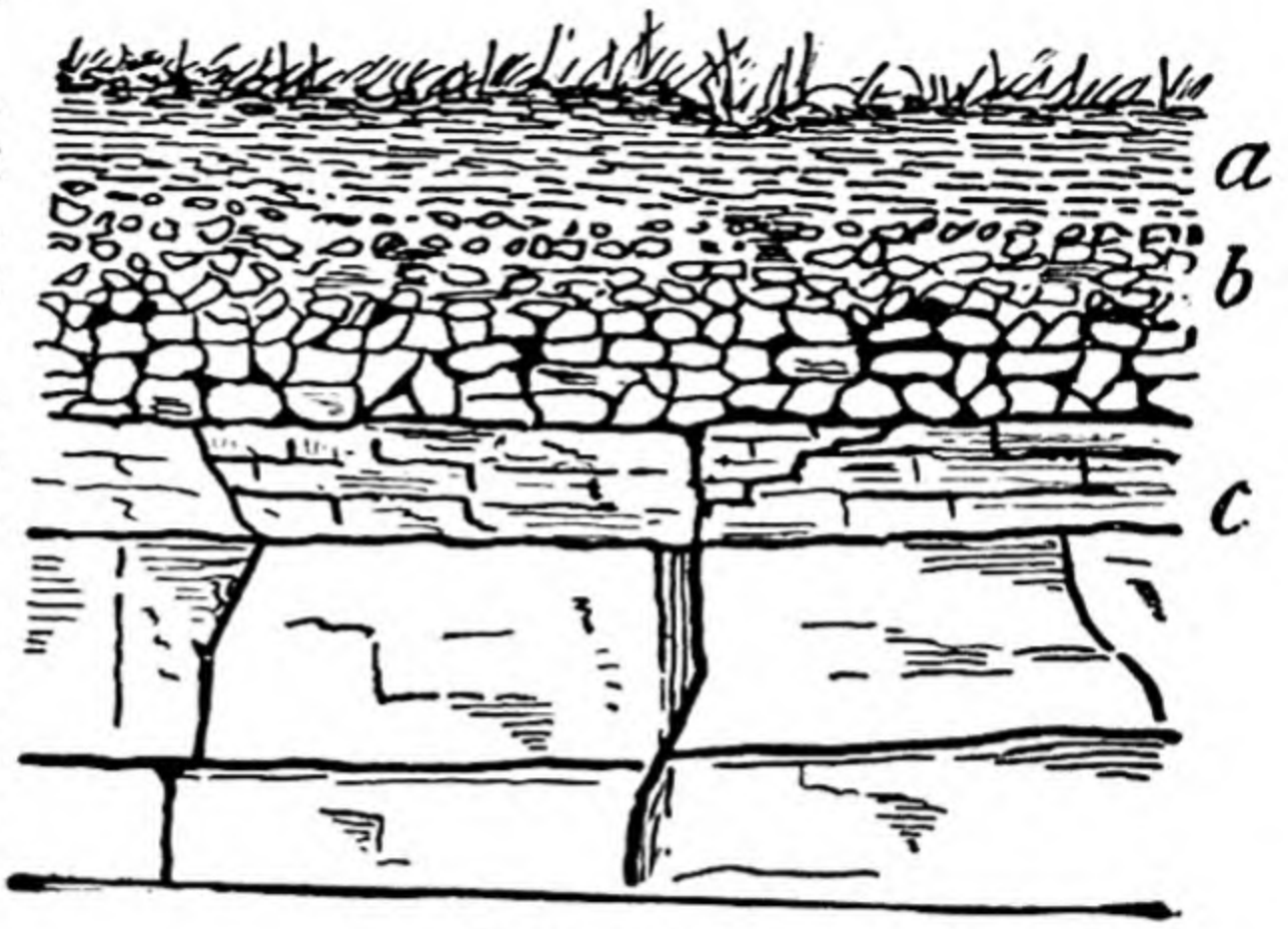


FIG. 133.

a, soil; *b*, subsoil; *c*, subjacent rock.

Solar System (Lat. *sol*, the sun). The solar system consists of the sun and all those heavenly bodies whose motions are controlled by its gravitation—viz. the planets with their satellites, the comets, and certain of the bodies called meteors. solar system (*see* fig. 134).

The Earth is one of the planets of the

According to the Geography The political boundaries are of no use.

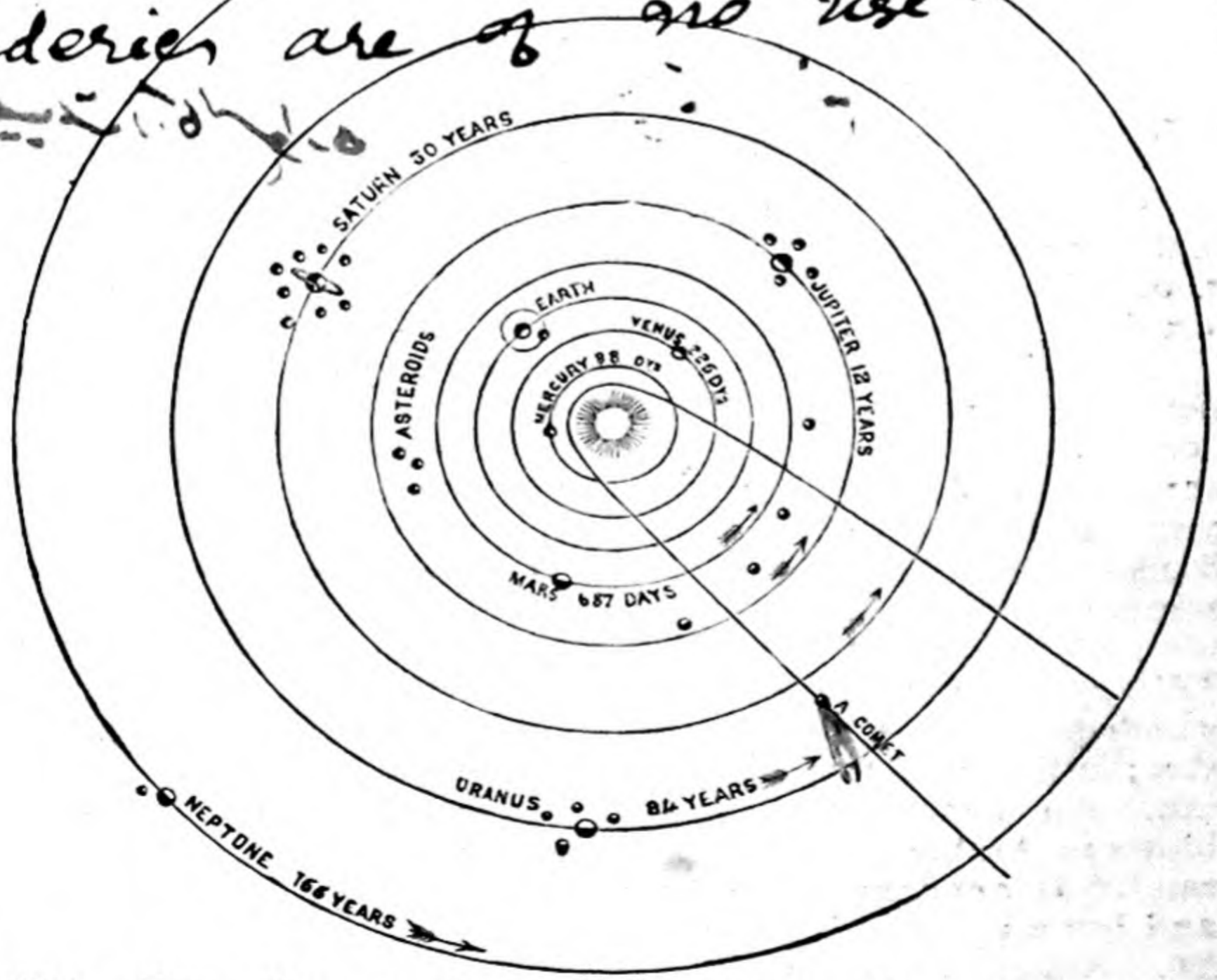


FIG. 134.—THE SOLAR SYSTEM, SHOWING SUN, PLANETS, AND SATELLITES.

Solfatara (Ital. *solfo*, sulphur). A volcanic fissure or other orifice from which sulphurous vapours, hot mud, and steam are ejected, frequently giving rise to mud volcanoes or salses.

Solstices (Lat. *sol*, the sun; and *sto*, I stand). The solstices are the dates (June 21 and December 22) on which the sun is vertically overhead at noon at the tropics, because then he appears to stop in his northward or southward course before turning in the opposite direction. On June 21 the sun is vertical at noon at all places on the Tropic of Cancer; on December 22 at all places on the Tropic of Capricorn. (*See* Pars. 6 and 92.)

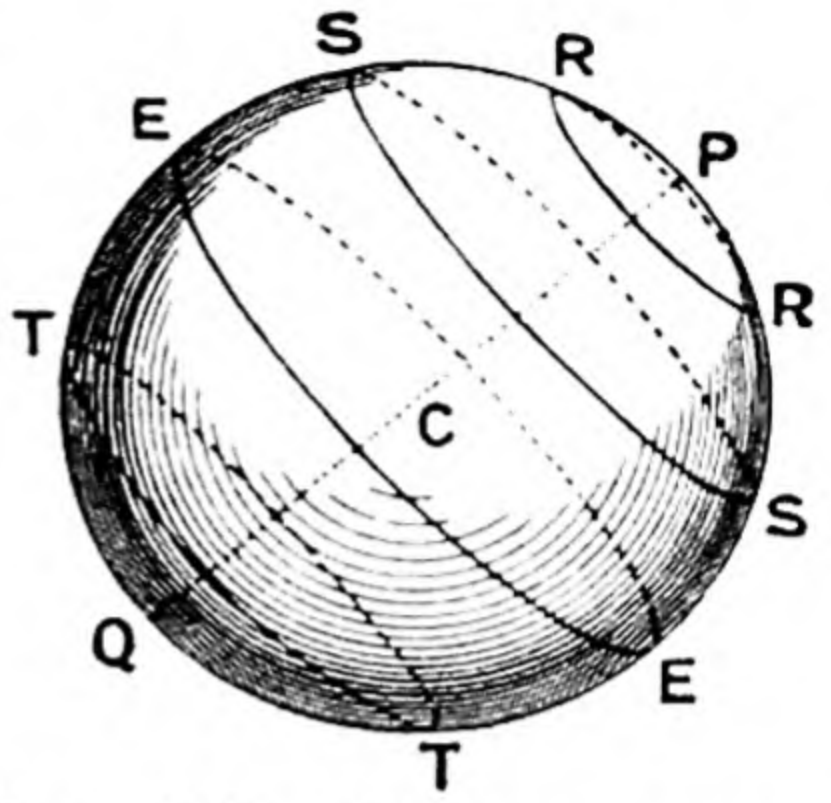


FIG. 135.—GLOBE, WITH GREAT AND SMALL CIRCLES.

Sphere. A sphere or globe is a round body bounded by a curved surface, every point on which is equally distant from the centre. A section made by a plane passing through the centre of a sphere cuts the surface of the sphere in a **great circle.** Any number of great circles may be drawn upon a sphere. All great circles are equal to one another, and any two bisect each other. Any section of a sphere made by a plane not passing through the centre cuts the surface

See page 210.]

[*Photo: E.N.A.*

FIG. 136.—CAVERN, SHOWING STALACTITES AND STALAGMITES.

in a **small circle.** Great circles are of importance in navigation, as distance on the arc of a great circle is the shortest distance between any two points on the surface of a sphere.

Spring Tides. The tides which occur at or near the new or full moon, rising higher than the common tides. At these tides the sun and moon are in a straight line with the earth, and their combined influence in raising the waters of the ocean is the greatest.

Stalactite (Gk. *stalaktos*, a dropping). A mass of calcareous matter attached like an icicle to the roof of a cavern. It has been produced by the percolation through the rock above of water holding calcium carbonate in solution, and then evaporating.

Stalagmite (Gk. *stalagmos*, dropping). A mass of calcium carbonate formed on the floor of a cavern in a similar manner to stalactites, They are often both found together, sometimes growing until they meet in the centre, thus making a pillar of calcium carbonate.

Steppes (Russian *stepi*, a waste or heath). Extensive plains or grasslands in S.E. Russia and the adjoining parts of Asia. The scanty rainfall, short summer and severe winter prevent the growth of trees, but grass abounds, so that cattle-rearing is carried on. Wheat and maize can be grown in the damper parts.

Stratum, plural **Strata** (Lat. *stratum*, something spread out, a sheet). The strata are the layers of material forming sedimentary rocks, which are then said to be stratified. As first formed these beds or strata were probably horizontal, but may have got subsequently displaced by volcanic action (*see* fig. 113).

Striated (Lat. *striae*, streaks). A term applied to ice-scratched rocks, the scratches being known as *striæ*.

Subsidence (Lat. *sub*, under; *sido*, I sink, or settle down). A sinking of a portion of the earth's crust. The land may subside suddenly or very gradually, and over a small or large area.

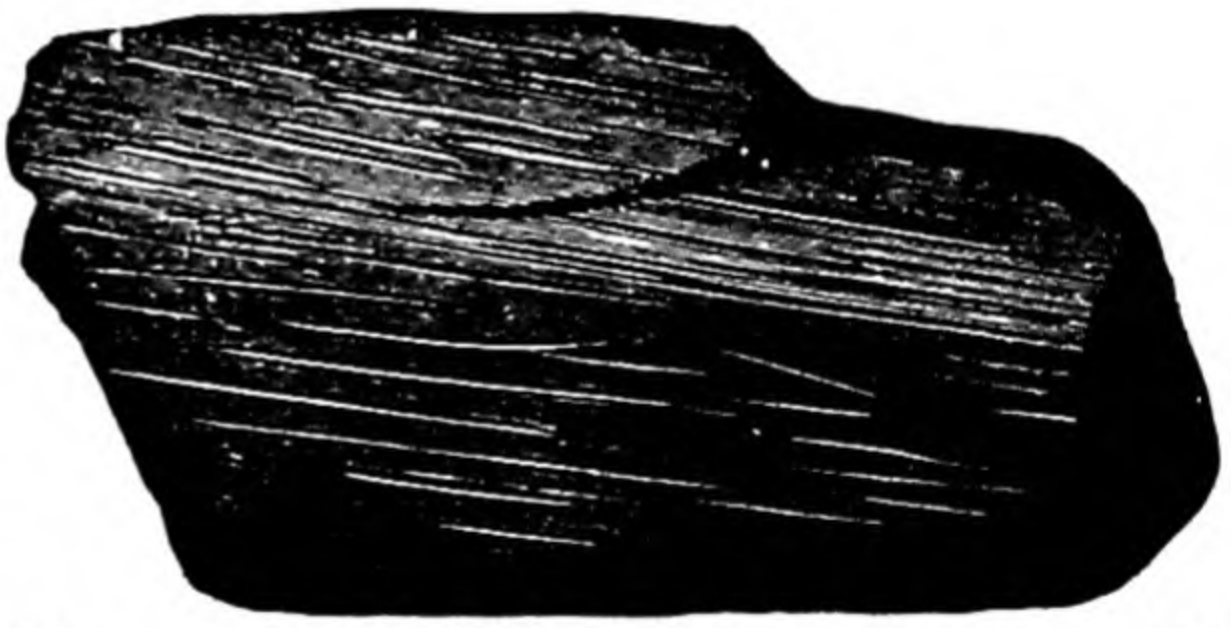


FIG. 137.—STRIATED BLOCK OR SCRATCHED STONE FROM A GLACIAL DEPOSIT.

Sundial. The essential parts of a sundial are a rod or the edge of a triangular piece of metal called a *style*, which is placed parallel to the earth's axis, and a horizontal plate called the *dial*. The plate is marked out with the different hours of the day, and the shadow of the style cast by the sun passing over it, as the sun moves through the sky, indicates the time of day. As the sun rises in the east, the shadow falls to the west; as the motion progresses, the sun moves to the south and the shadow to the north (in the Southern Hemisphere 'south' and 'north' must here be interchanged) till at noon it is due north, and on the mark indicating XII. In the afternoon the shadow passes eastward. The figure (fig. 138) shows the usual form of a horizontal sundial. This indication of time, depending on the motion of the sun, will not necessarily agree with the indication by a clock; for the true

solar day, or length of time from noon to noon by the sun, is not of constant length at all periods of the year. In fact, the sundial indicates 'true solar time,' the clock indicates 'mean solar time.' As just stated, the *style* or *gnomon*, which is usually a rod or edge of a triangular thin plate of metal, must be *parallel to the earth's axis*. It must, therefore, point to the celestial pole, and make an angle with the horizontal dial-plate equal to the latitude of the place. At London this angle will be 51½°, at Edinburgh 56°, and thus a dial, serviceable at one latitude, will be of no use at a different latitude. Since the daily apparent motion of the sun due to the earth's rotation appears to carry it round the earth's axis in twenty-four hours, the sun also appears to travel round the style of the dial, and it thus casts the shadow of the style upon the side of the dial away from the sun. At noon, when the sun is in the meridian of the place of observation, the shadow will be shortest and cast exactly north. As the sun appears to move through 15° each hour, the position of other hour-lines on the dial-plate may be found by marking the position of the shadow at the end of each movement of the sun through 15°. The graduations that mark the hours on a dial-plate are not at equal intervals, as the plane of a horizontal plate is not perpendicular to the earth's axis, except at the poles. Vertical sundials are placed on a wall and for one facing the south the style will have an inclination equal to the latitude of the place subtracted from 90°.

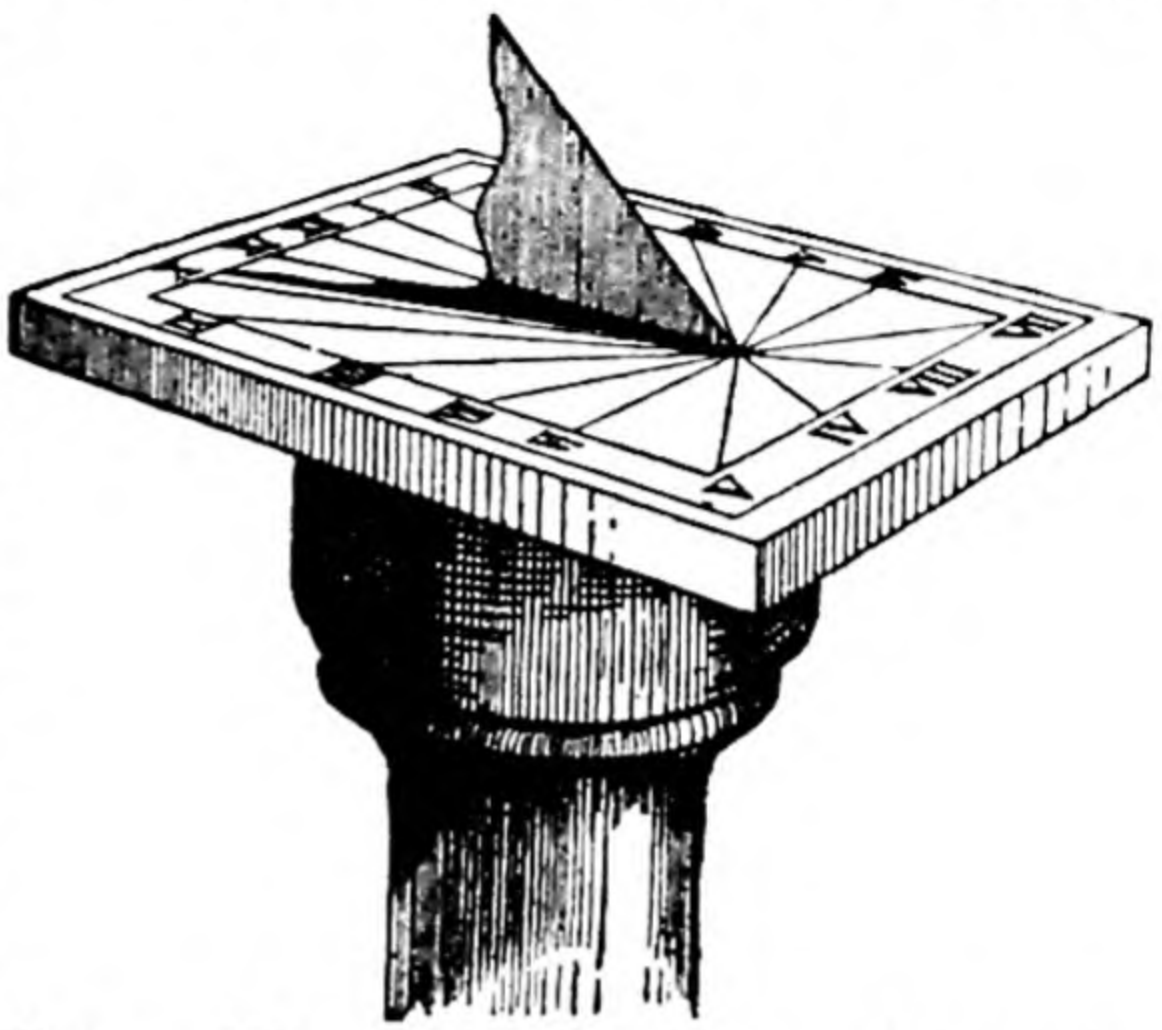


FIG. 138.—HORIZONTAL SUNDIAL, WITH SHADOW OF STYLE INDICATING 10.15 A.M.

Tableland. A flat or level tract of land raised above the surrounding surface of the country; a plateau (*q.v.*).

Talus. *See* 'Scree.'

Terrace (Lat. *terra*, the earth). A bank or shelf of land, nearly level, extending along the margin of the sea, a lake, or river. (*See* River Terraces, Par. 54*a*.)

Thermal (Gk. *therme*, heat). Of or pertaining to heat, warm; *e.g.* thermal springs are springs in which the water has come from a considerable depth in the earth's crust, and is therefore warm. (*See* Par. 54.)

Tornado (Sp. *tornar*, to turn). A violent cyclonic storm or whirlwind, accompanied by vivid lightning, deafening thunder, and torrents of rain. Though very destructive, it is small in extent, and lasts only for a short time. They are commonest in the United States east of 100° W. (*See* Par. 23.)

Torrid Zone (Lat. *torridus*, parched, burning). That belt of the earth's

surface ($23\frac{1}{2}°$ on each side of the equator) lying between the tropics.

Trade Wind. (*See* Par. 20.)

Tributary (Lat. *tributum*, a tribute). A river or stream which contributes its waters to another, usually larger than itself; an affluent (*q.v.*).

Tropics (Gk. *trope*, a turning). The tropics are two circles drawn round the earth parallel to the equator, at a distance of $23\frac{1}{2}$ degrees on each side of it. The southern tropic, called the Tropic of Capricorn, has the sun vertically overhead on December 21. He then moves northward, and the sun is vertical at the northern tropic, called the Tropic of Cancer, on June 21. At all places between the tropics —that is, in the tropical or torrid zone—the sun is vertical twice during the year, but at places beyond the tropics the sun is never vertical. (*See* Pars. 6 and 92.)

Tundras. Flat, marshy, treeless plains occurring in Northern Russia and Siberia, and frozen hard in winter. In the short summer a few inches of the surface thaws, and the marshy ground is then covered with lichens, mosses and low berry-bearing bushes. The inhabitants are hunters and fishermen (Lapps and Samoyedes) who use the reindeer as a domestic animal. Polar bears and Arctic foxes are found. Remains of the Mammoth, an extinct shaggy-coated elephant, have been dug out in parts of the tundras.

Twilight. The faint light from the sky when the sun is below the horizon at morning and evening. It is due to sunlight reflected from the upper parts of the atmosphere, and lasts only as long as the sun is less than 18° below the horizon. The time taken by the sun to reach this limit is longer in high latitudes than near the equator, as its path is there more inclined to the horizon. It also varies with the season of the year.

Typhoon. A violent prolonged cyclonic storm of great intensity, which often occurs in the China seas during the months of July, August, September, and October.

Valley. A depression or low-lying tract of land between hills or mountains, and often traversed by a stream or river, which carries off the drainage of the higher ground. Valleys which run along the line of a mountain chain between its parallel ranges are called *longitudinal valleys*; valleys which run across the length of the chain between its peaks are termed *transverse valleys*.

The origin of valleys is various, so that according to origin there are various kinds of valleys. Some are due to the structure of the ground. Valleys due to the structure of the ground are either *synclinal* valleys or *rift valleys*. A synclinal valley is found where the ground has been thrown into parallel folds, the upfolded ridge being an anticline, and the hollow forming the valley a syncline. Synclinal valleys soon suffer changes, for the anticlinal fold is weakly built, and the synclinal structure firm. The top of the fold, therefore, may be quickly removed, and the syncline filled up. *Rift valleys* are dislocation valleys lying between parallel faults, the land having sunk between the faults. Such is the valley in which the Jordan flows. Most valleys are, however, more or less due to the erosive action of running water, being, in fact, produced by the action of rivers (Par. 54*a*). Such erosion valleys are either *longitudinal valleys* running parallel to mountain

ranges, or *transverse valleys* cutting through the strata of a range at right angles. A transverse valley may be due to a break in a mountain chain, but may also be the result of river erosion which has kept pace with the uplifting of the mountain chain that it crosses. A river passing into a desert region where the strata are horizontal, cuts out a deep narrow valley called a cañon, for in such a dry region there is little weathering at the sides to widen the valley. The term *lateral* valley is used to describe the smaller valleys down which tributaries run into a large stream flowing in a longitudinal valley. River valleys are of various ages, or in different stages of development, as is seen by their depth and width (*see* 'Flood Plains'), for a river valley is mainly the combined action of stream erosion, which deepens its bed, and weathering which lowers and broadens the sides (Par. 54*a*).

Vitreous (Lat. *vitrum*, glass). Containing or resembling glass in its form, structure, etc.; *e.g.* vitreous rocks, like obsidian.

Volcano (Lat. *Vulcanus*, the God of Fire). A hill of varying size, having at the top a cup-shaped cavity, termed the crater, from which a tube or pipe passes into the heated interior of the earth. At

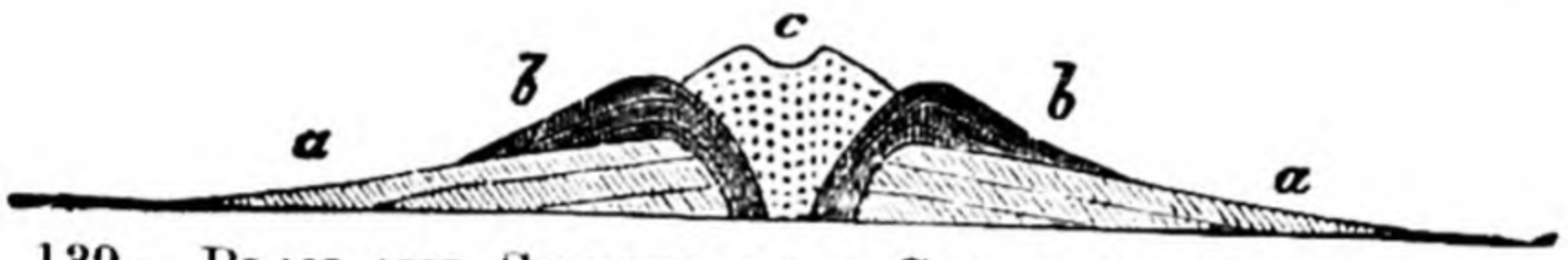


FIG. 139.—PLAN AND SECTION OF A COMPOSITE VOLCANIC CONE.
a, ruff; *b*, lava; *c*, ashes and scoriae.

intervals, through this pipe a discharge of steam, hot gases, stones, and lava takes place. The conical hill is itself built up of layers of matter discharged from the volcano. (*See* Par. 48.)

Waterfalls. When a stream is deepening its bed, a difference in the hardness of the rocky strata over which it flows usually leads to a waterfall or rapids. Soft rocks are eroded more quickly than hard rocks, so that when a stream passes from a hard layer to a soft layer, the latter is more quickly removed and a fall is formed, the edge of the hard layer being the position of the fall. As the weaker strata below are removed and a hole made at the foot of

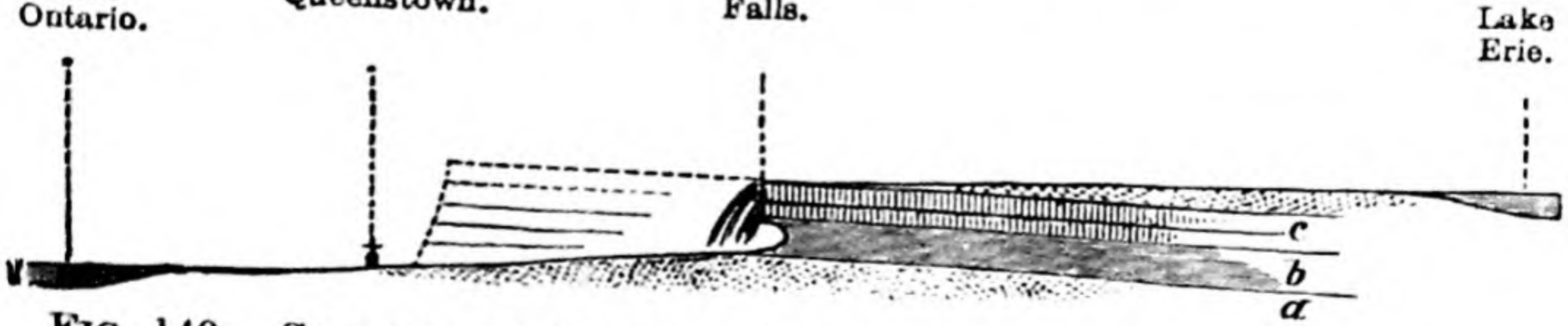


FIG. 140.—SECTION SHOWING THE ROCKS AT THE FALLS OF NIAGARA.
a, sandstone; *b*, shale; *c*, beds of limestone.

the fall, the hard layer above gets undermined, and a projecting ledge is formed. In time this breaks off and the fall retreats up

stream, forming a gorge or ravine below. The falls of Niagara, 165 feet high, are an example of a typical fall. They are situated at the head of a gorge about 300 yards wide, 200 to 300 feet deep, and seven miles long. The water pours over a bed of hard limestone, beneath which are softer beds of shale easily worn away. The falls are retreating and the gorge growing longer at the rate of four or five feet a year. They were originally at the edge of a steep bluff near the town of Queenstown. Among the sloping beds of limestone and shale in the Yorkshire dales similar falls and gorges on a smaller scale occur; the falls of Clyde are also due to a similar cause. Fractures of rock causing a downthrow on one side across a river valley may also lead to a waterfall. The Victoria Falls on the Zambesi River have been thus produced. The falls are 2,000 feet wide and 450 feet high, and in the rainy season a vast volume of water drops into a rift to escape through a narrow zigzag ravine. Falls are numerous in lateral streams that flow into a main stream that has sunk its channel more rapidly and deeply than the side tributaries. Villages and towns often grew up near the waterfalls, as the descending water was made to turn water-wheels and drive machines, but waterfalls and rapids are now much used to supply electrical energy, which can be transmitted by wire to distances of many miles. The falling water is led through pipes and made to drive machinery that generates an electric current. The current from Niagara is used by manufacturing towns up to 300 miles away; many Swiss towns obtain their electric supply from a similar source; and it is proposed to use the Victoria Falls of the Zambesi River to supply electric energy to the mines of Kimberley.

Watershed (water, and A.-S. *sceadan*, to divide). A water-parting. The ridge of land separating the waters flowing into two different river basins. Also applied to the slope down which waters drain (*see* fig. 141).

FIG. 141.—NORTHERN WATER-PARTING.

Waterworn. Rounded or smoothed by the action of water. Masses of stone merely weatherworn are rough and angular. Ice-borne rocks are also angular, and often striated.

Wave. A swell or ridge on the surface of water; an undulation. (*See* Par. 37.)

Weathering. The term used to describe the action of the atmosphere on the rocks of the surface as its oxygen, carbonic acid, moisture and varying temperature (heat and frost) lead to decomposition and disintegration of rock. (*See* Pars. 52 and 53.)

Weather Charts. A weather chart is a map of a certain area of the earth's surface on which are indicated the isobars (on the example given for every difference of four millibars or about $\frac{1}{8}$ inch in the barometric pressure), the direction and force of the wind, the temperature of the air, and the state of the sky at a certain hour. These indications are the result of telegraphic and wireless messages from various observing stations in the area, including ships at sea, and as they give a general view of the whole weather in an area, they are often called **synoptic weather charts.** Synoptic Charts of the North Atlantic as well as for the greater part of the Northern Hemisphere are issued daily by the Meteorological Office, and one

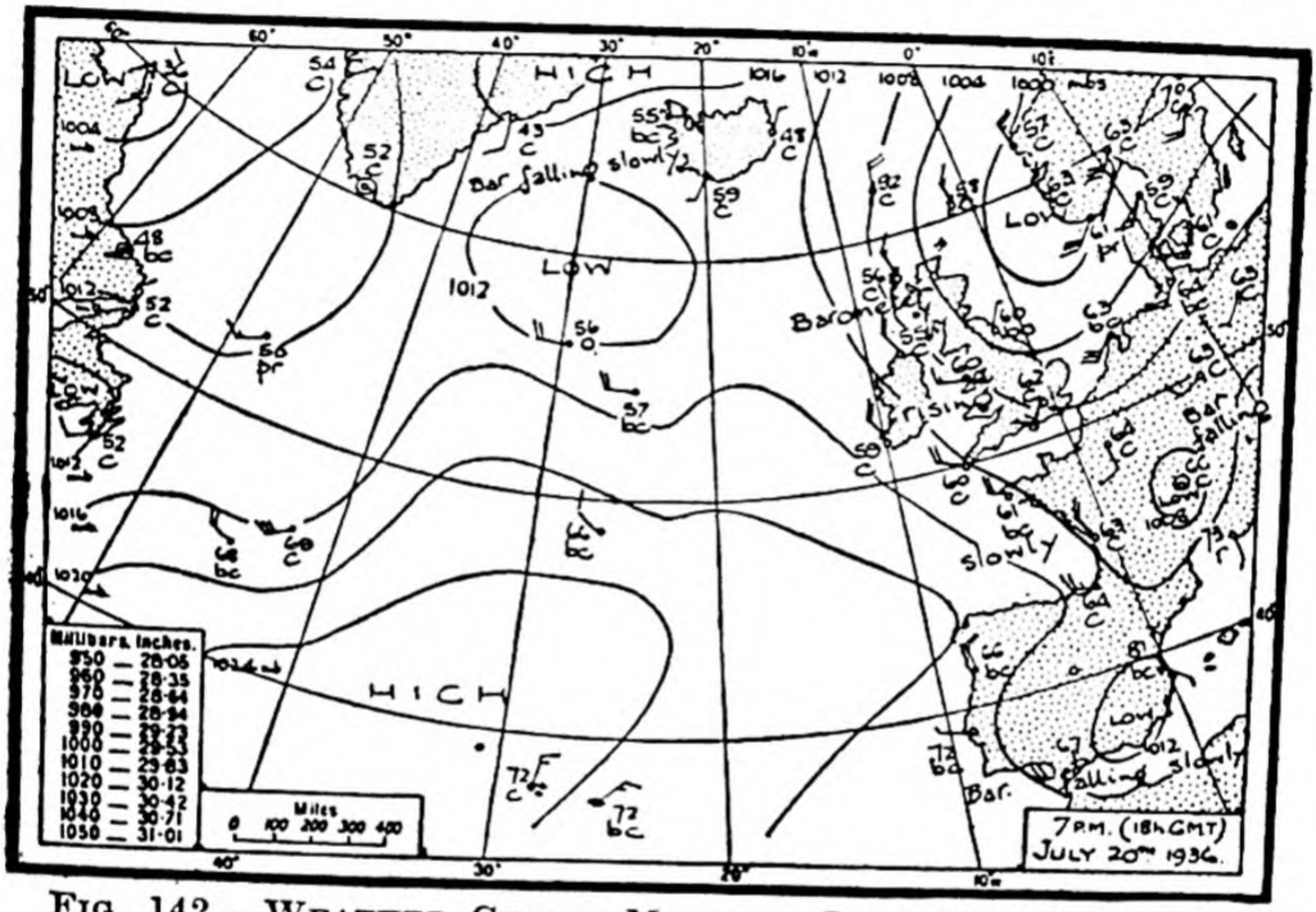


FIG. 142.—WEATHER CHART, MONDAY, JULY 20, 1936, 7 P.M. (SUMMER TIME) (18h G.M.T.)

In the above chart the dotted lines are 'isobars,' or lines of equal barometrical pressure, the values which they indicate being given in figures at the end, thus—1020 (millibars). The shade temperature is given in figures. Light wind, ; fresh or strong, : a gale, .

is published daily in the *Times* newspaper. A study of a series of charts is very instructive. Before noticing such charts we must remember that reasoning and observations have established the following two laws: (1) Air blows from regions of high barometric pressure to regions of lower air pressure; (2) in consequence of the earth's rotation on its axis from W. to E. air currents are deviated to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere (*see* 'Ferrel's Law'). It results from the above that air does not stream directly into a region of low pressure, but leaves this on the left hand, so that it has a turning movement round a cyclonic depression in a direction

opposite to the hands of a watch. The air from a region of high pressure (anti-cyclonic area) moves under the same influences, only as the movement is from a centre of high pressure outwards the turning is from left to right or in the direction of the hands of a watch. In both cases the region of low pressure is on the left. Hence a general rule called Buys Ballot's Law may be thus stated: *Stand with the back to the wind and the lowest pressure lies to the left and somewhat in front.* The highest pressure will be to the right, somewhat behind. We may transpose the above as: Stand with

WEATHER CHART

For the Week ending Wednesday, September 7. 1897.

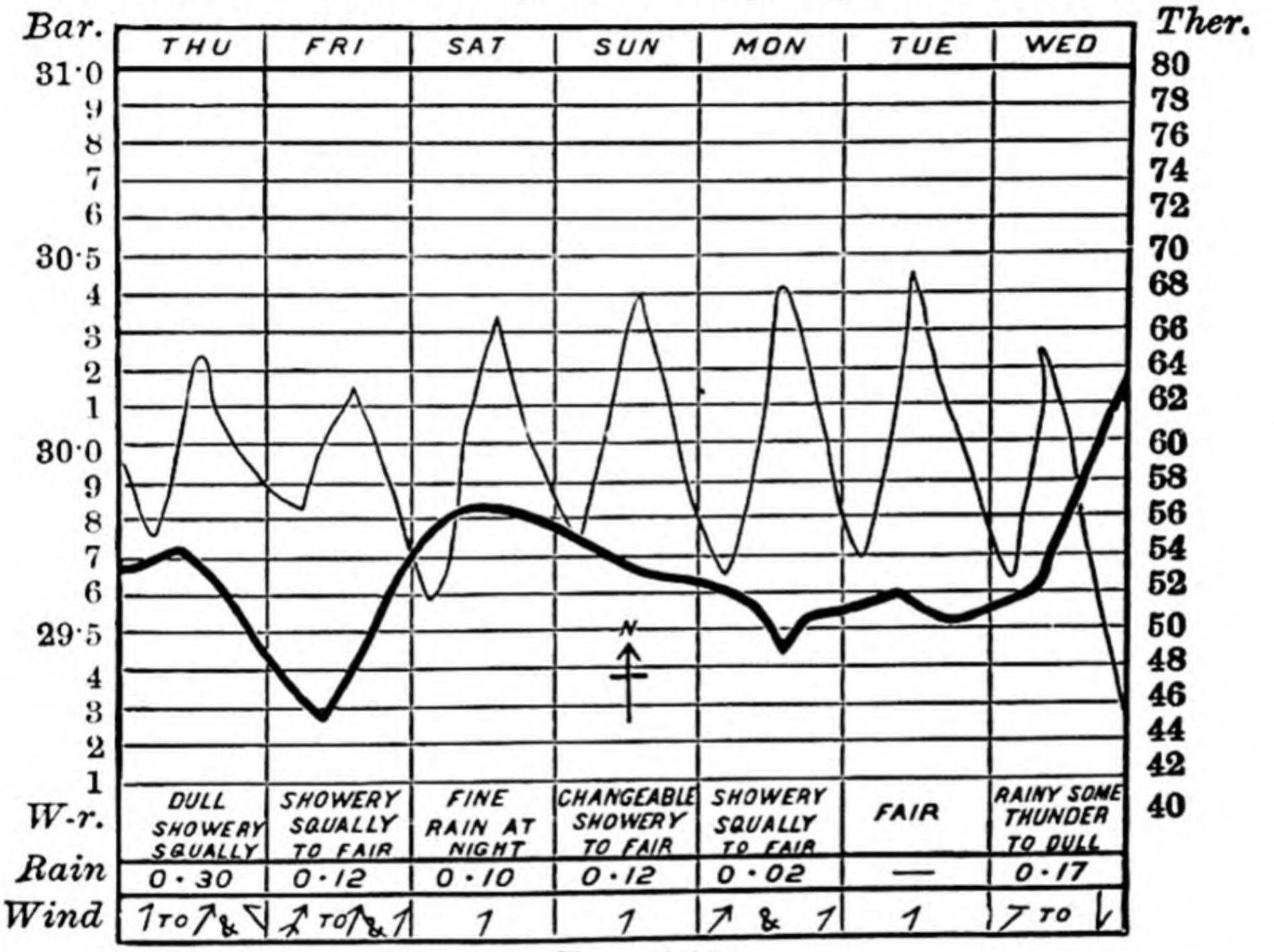


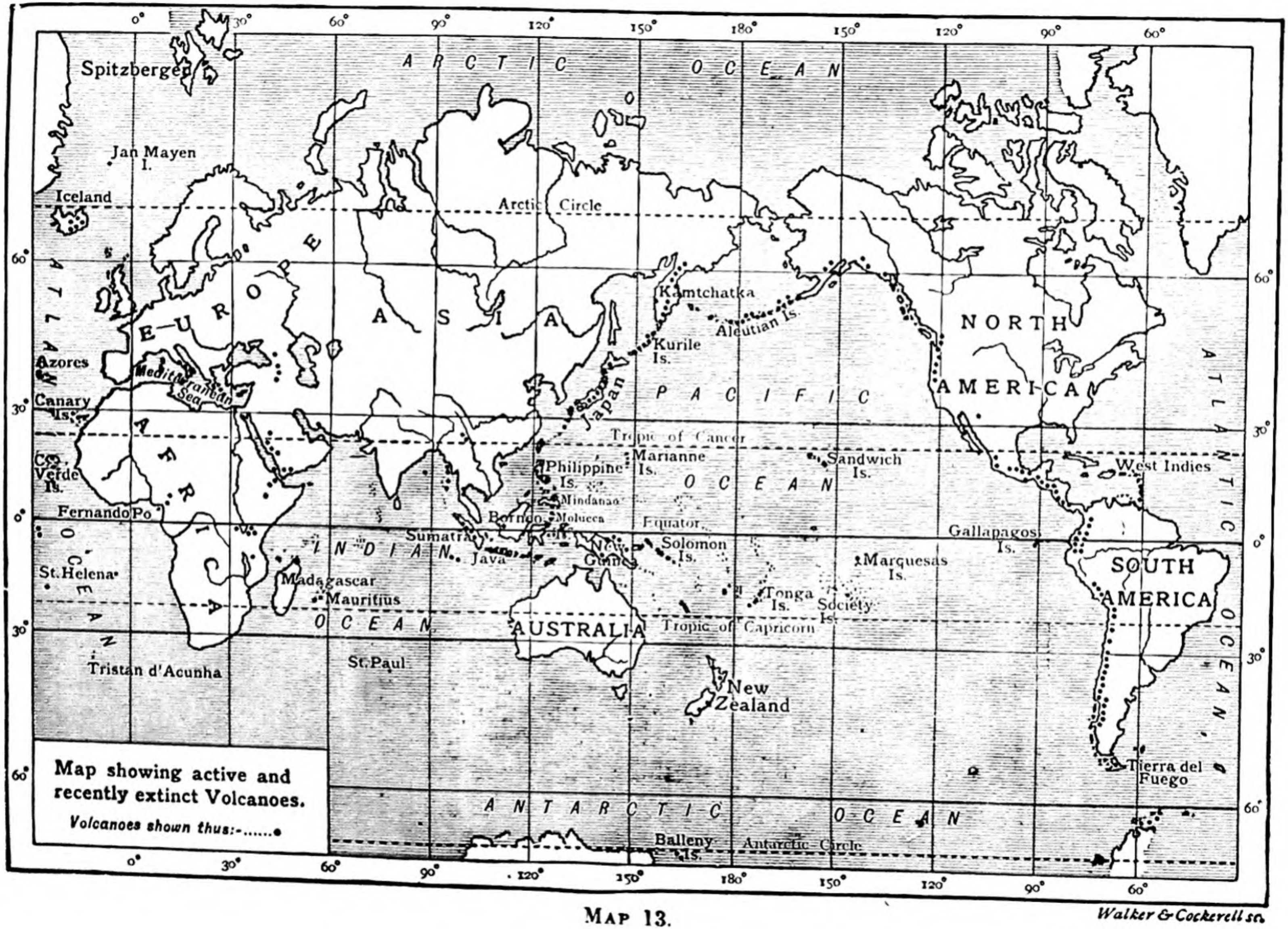
FIG. 143.

EXPLANATION.—The thick line shows the variations in the height of the barometer during the week ending Wednesday midnight (7th Sept.). The fine line shows the shade temperature for the same interval, and gives the maximum and minimum readings for each day, with the (approximate) time at which they occurred.

the lowest barometric pressure to the left and in front, and the wind will blow on your back. (For the southern hemisphere left and right must be interchanged.) We thus come to a relation between the wind and isobars, and find that *the wind moves nearly along the isobars, tending to cross from the higher ones to the lower ones.* It is as a rule inclined to the isobars at an angle of from 30° to 40°. The two chief types of isobars are those associated with cyclonic areas and anticyclonic areas. (*See* figs. 142 and 24, and note the relation of the wind to the isobars.) In the cyclonic area the wind rotates round the centre in a direction opposite to

watch hands, and the arrows are nearly parallel to the isobars. Hence in the front (cyclones move on to the north-east in northern latitudes) the wind is from the south-east ; farther round it is from the east-north-east ; still farther round from the north-north-east ; then from the west nearly ; and lastly from the south-west. Moreover, in front the wind is somewhat incurved towards the central barometric depression and therefore somewhat across the isobars, while in the rear it is more nearly parallel to the isobars. Its velocity, as indicated by the number of barbs on the arrows, increases with increase of the *barometric gradient*—that is, with the closeness of the isobars. As to the weather associated with a cyclone, it is in general squally and showery. In front of the cyclone we have mist and cloud ; nearer the centre drizzling rain. At the centre there is a sharp downpour ; while in the rear are cool dry winds. As a cyclone passes over any area the wind and weather undergo the changes indicated above. Copy the isobars of fig. 142 and then try to put in the arrows for the wind and names indicating the weather in each part of the cyclonic area. Fig. 24 shows the arrangement of isobars, wind and weather associated with a cyclone. A common condition of the air in the British Isles shows the isobars running in a nearly straight line across the country in a north-easterly direction, and showing a barometric pressure increasing from south to north. In accordance with what has been said the arrows will indicate a south-west wind or south-south-west, and such a wind usually brings rain to our islands. Other types of isobars and weather will be found on examining a series of weather charts. These may be obtained for one penny each, plus postage, from the Meteorological Office, London, S.W.7, and useful exercises may be based upon them. The relation of the weather to the shape of the isobars will also be seen after a number have been examined. In connection with weather charts the issue of storm warnings may be noted and the hoisting of *storm signals*. The probability of a strong wind is indicated at coast stations by the hoisting of a large cone of canvas by day or three lamps on a triangular frame by night. The *south cone* or its corresponding triangle has its point downwards, and indicates strong winds from S.E. veering to S. and to N.W. The *north cone* or its corresponding triangle indicates strong winds from N.W. veering to N. and N.E.

Weather Diagrams. Besides daily synoptic weather charts, various diagrams are prepared as the result of observations made several times a day at some particular place. The thermometer and barometer are noted at certain hours during each day, and the results may then be graphically represented for a week, as in fig. 143, the record referring to London. Note that the maximum daily temperature occurs some time after midday (about 2 o'clock), and the minimum daily temperature about two hours after midnight. The barometer was highest (30·2 inches) on Wednesday ; lowest (29·28) on Friday. The temperature was highest (69°) on Tuesday ; lowest (52°) on Saturday ; range 17°. Rain fell on six days, 0·3 inch being the heaviest fall on Thursday. The fall was 0·89 inch. The reader should make his own observations for a week and construct a similar diagram on squared paper. Every sixth upright line may be thickened to mark off the separate days.


0° 30° 60° 90° 120° 150° 180° 150° 120° 90° 60°
Spitzbergen
ARCTIC OCEAN
Jan Mayen I.
Iceland
Arctic Circle
60°
EUROPE
ASIA
Kamtchatka
Aleutian Is.
Kurile Is.
NORTH AMERICA
ATLANTIC OCEAN
Azores
Mediterranean Sea
Canary Is.
Japan
PACIFIC OCEAN
30°
Tropic of Cancer
Marianne Is.
Sandwich Is.
West Indies
C. Verde Is.
Philippine Is.
Mindanao
Fernando Po
Borneo
Molucca
Equator
Sumatra
Solomon Is.
Gallapagos Is.
AFRICA
INDIAN OCEAN
Java
New Guinea
Marquesas Is.
St. Helena
Madagascar
Mauritius
Tonga Is.
Society Is.
SOUTH AMERICA
AUSTRALIA
Tropic of Capricorn
Tristan d'Acunha
St. Paul
New Zealand
Tierra del Fuego
ANTARCTIC OCEAN
Balleny Is.
Antarctic Circle
Map showing active and recently extinct Volcanoes.
Volcanoes shown thus:-.....•
Walker & Cockerell sc.

MAP 13.

Windward. Applied to the face of a hill or ship on which the wind blows ; the weather side.

Zenith. The point in the heavens which is vertically above the head of the observer.

Zenith Distance. The angular distance of the sun or other celestial object from the zenith.

Zone (Gk. *zone*, a girdle or band). One of the five belts or bands of the earth's surface, bounded by certain parallels to the equator, as fixed by the apparent position of the sun in the course of a year, the position of the parallels being determined by the apparent movements of the sun north and south of the equator. The zones are (*a*) the **Torrid Zone,** 47° in width, extending on both sides of the equator from the Tropic of Cancer to the Tropic of Capricorn; (*b*) two **Temperate Zones,** each 43° in width. The north temperate zone extends from the Tropic of Cancer to the Arctic Circle; the south temperate zone, from the Tropic of Capricorn to the Antarctic Circle; (*c*) two **Frigid Zones,** each 23½° from the pole in width, extending from the polar circles to the north and south poles respectively. The zones are very unequal in area, the Torrid Zone occupying $\frac{4}{10}$ths of the earth's surface, the two Temperate Zones a little more than $\frac{5}{10}$ths, and the two Frigid Zones a little less than $\frac{1}{10}$th. Smaller belts or zones than the above are also made, each distinguished by special forms of animal or vegetable life. (*See* the eight zones of plant distribution, Par. 65.) There are also certain zones of winds and calm. (*See* 'Climatic Zones.')

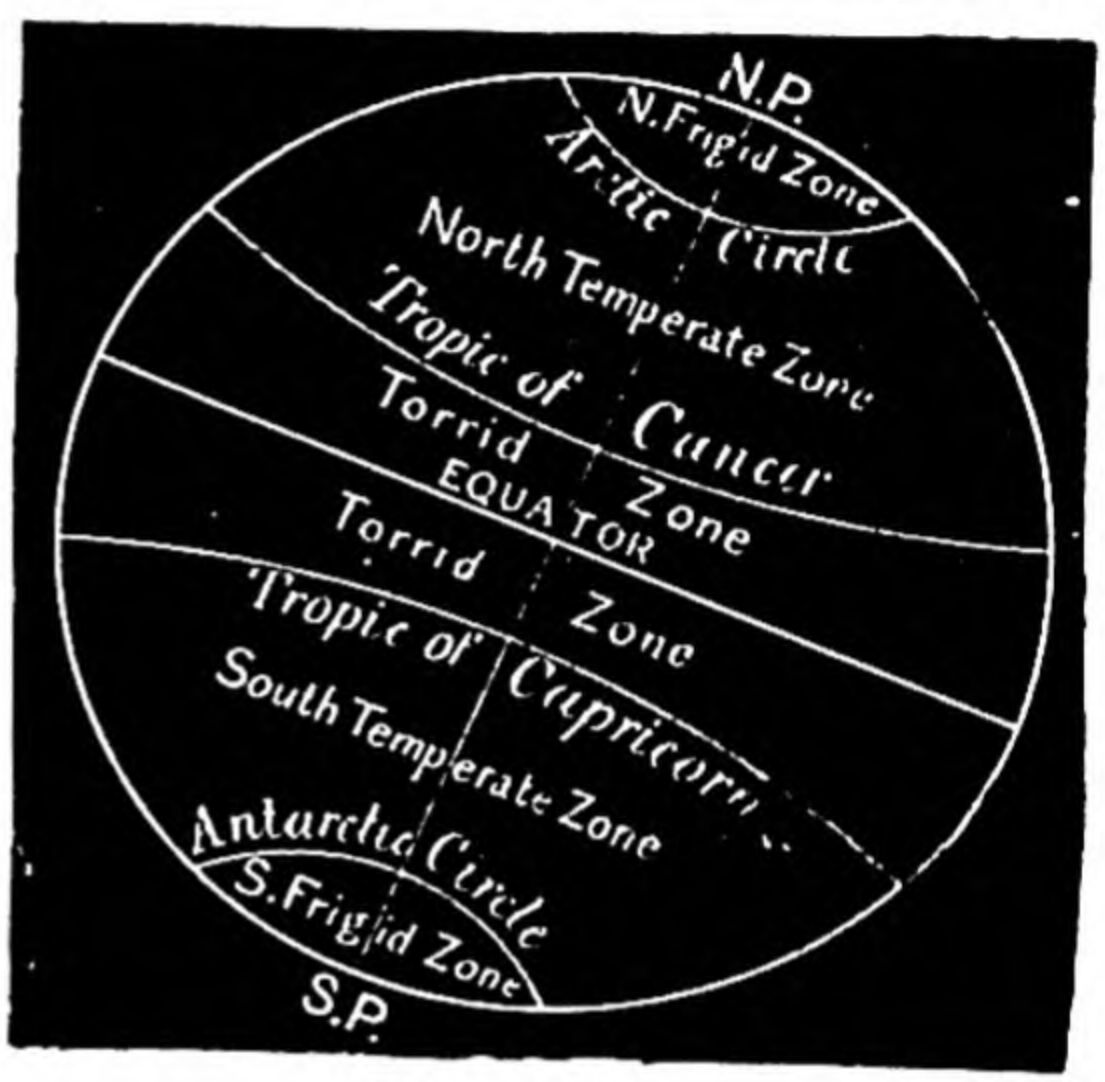


FIG. 144.

EXAMINATION QUESTIONS

(With Occasional Hints for Answers.)

(Illustrate your answer with drawings or diagrams when possible.)

1. Give proofs of the globular form of the earth. Point out why it is not 'round' in the sense that a coin or cylinder is 'round.'

2. How are latitude and longitude reckoned? What is the greatest latitude a place can have? the greatest longitude?

3. When it is noon at London, what will be the time at Hamburg, 10° E. long., and at San Francisco, 122° 20′ W.? How is time lost or gained when travelling east or west?

(For a place east of Greenwich *add* 4 minutes for every degree, for a place west of Greenwich *subtract* 4 minutes for every degree, to get the local time.)

4. What is the cause of the varying length of day and night at all places north and south of the equator? Give the length of the longest day at Cairo, 30° N., at London, and on the Arctic Circle.

5. Why is it so much warmer in summer than in winter?

6. 'The cause of the seasons is the revolution of the earth round the sun.' Point out why this statement is defective, and explain in full the causes of the seasons in the temperate zones.

7. 'In New Zealand the seasons are the opposite of those in England, and it is night there when it is day with us.' Explain the reasons of the above statement.

(New Zealand is nearly the antipodes of England, and it is plain that places not on the equator that are the antipodes of each other will be in different hemispheres as regards the equator, and on opposite sides of the same meridian, 180° of longitude apart, as they are diametrically opposite.)

8. Point out:—

(*a*) The direction in which the earth rotates on its axis.
(*b*) Why the surface of the earth is divided into five zones.
(*c*) How we know when the earth is in perihelion.
(*d*) Why and how we know that the earth's axis remains parallel to itself during its revolution round the sun.

9. In what parts of the world does the division of the year into four seasons seem inexact and unsuitable, and why?

10. Explain the reason of—(*a*) the varying altitude of the midday sun, (*b*) the inequality in the length of the seasons.

11. Explain the terms:—**Axis of rotation, high latitudes, ecliptic, equinox, solstice, tropic.**

12. How could you determine by the aid of the sun's shadow—(*a*) The meridian line of any place, (*b*) the date of the winter solstice, (*c*) the length of a year?

13. What is the exact shape of the earth? How has it been found?

Give the length of a degree of latitude and a degree of longitude at the equator, in England, and at the north pole.

14. State—(*a*) Why it is incorrect to say that the earth is a little flat at the top and bottom, (*b*) why it is incorrect to say that the earth's axis is inclined to the plane of its orbit 23½°, (*c*) how often the sun rises exactly in the east and sets exactly in the west, (*d*) why the distinction between 'great circles' and 'small circles' is important to navigators. (*See* Glossary, 'Sphere' and 'Great Circle Sailing.')

15. Name the gases that are found in dry air, giving the proportion of each in 100 volumes. What other substances are usually found in the atmosphere ?

16. What regulates the quantity of water-vapour present in the air ? When is the air said to be saturated ? Will there be more vapour in saturated air in summer or in winter ?

17. How is the pressure of the atmosphere measured ? What is the effect of taking a barometer up a mountain or into a deep mine ?

18. What causes lead to changes of atmospheric pressure ? Explain the term **isobar.**

19. Explain clearly how the air is warmed, and why it is colder on the summit of a mountain than at the foot. (Refer to Pars. 17 and 62.)

20. Why is the temperature of the air greater in the tropics than in the temperate zones, greater in summer than in winter, greater after noon than before noon ?

21. What is the cause of the **trade winds** ? Over what parts of the earth do they blow ? What is the cause of their easterly direction ?

22. Give an account of the monsoons of the Indian Ocean. What is their effect upon India ? In what other parts of the world are monsoons found ?

23. Tell what you know about the Equatorial Belt of Calms, the Roaring Forties, and a Tornado.

24. Describe a cyclonic and anticyclonic system of winds.

25. Give examples of **constant** winds, **seasonal** winds, and **local** winds.

26. Under what circumstances is dew formed ? Why is it often more abundant on grass than on gravel ?

27. What part do the **dust-motes** of the atmosphere play ?

28. How does a *fog* differ from a *mist* ? What are the chief varieties of clouds ?

29. How is rain formed ? What are the chief causes regulating the distribution of rainfall ?

30. Account for the great rainfall within the tropics, on the Khasi Hills, and on the west of Scotland.

31. Mention places that are deficient in rain, and account for the deficiency.

32. Define **snow-line,** and explain on what its height depends.

33. 'The amount of rainfall in a year is greatest within the tropics, though the number of rainy days in the year is fewest.' Give reasons for the above general statement.

(Evaporation is most abundant in the tropics owing to the greatest heat being there, and the heated air of this region can contain the greatest quantity of water-vapour in a given volume. As this heated air rises into higher regions of the atmosphere it is cooled, and condensation may occur before it passes polewards above, with a very heavy downfall as the result, as much falling in one hour as in a whole rainy day in the temperate zone, where the air cannot hold as much moisture. Yet, as the winds in the tropics are nearly constant, and in

higher latitudes more shifting and variable, rain occurs most frequently where cold and warm masses of air are most frequently brought together, as in the north temperate zone.)

34. What are the solids found dissolved in sea-water, and whence are they derived ?

35. Give some account of the form of the floor of the Atlantic Ocean, with a diagram. Where have the deepest ocean soundings been obtained—(*a*) in the Atlantic, (*b*) in the Pacific ? (*See* Par. 33.)

36. State the chief facts regarding the surface temperature of the ocean. How is the temperature affected by increase in depth ?

37. Name the chief deep-sea deposits, and describe one of them. Add a diagram (*see* fig. 42).

38. At what temperature does sea-water freeze ? Mention the chief forms of **marine** ice.

39. Describe the mode in which *icebergs* originate. What becomes of them ? How do they act as transporters of material from the land ?

40. What are the chief causes of waves and ocean currents ? How do waves affect the coast ? Why is the west of the British isles more indented than the east ?

41. Give some account of the origin, course, and effects of the Gulf Stream. What is the corresponding stream in the Pacific ?

42. Explain—(*a*) the effect of an ocean current on the climate of the west coast of America ; (*b*) how the currents of the Indian Ocean are affected by the monsoons.

43. Briefly explain what is meant by : Solar System, Saturated Air, Diatom Ooze, Pack Ice, Sargasso Sea, Cold Wall.

44. What causes the **ebb** and **flow** of the tide ? Does it always ebb and flow at the same rate ?

(Remember that the attraction of gravity decreases with the square of the distance, and that it is the greater attraction of the moon on the surface of the water under it than on the centre of the solid earth, 4,000 miles more distant, that is the real cause of the tides. Though the sun's attraction on the earth as a whole is far greater than that of the moon, yet its **differential** attraction on the two above parts is less, and hence its tide-producing force is less. (*See* Par. 42.) As each tide has only about six hours to **flow** and six hours to **ebb,** the highest tide must flow most quickly, and the lowest most slowly.)

45. Why is the high tide of one day about fifty minutes later than that of the preceding day ?

46. Account for **spring tides** and **neap tides.** Why are some spring tides higher than others ? Why is high tide at a place after the moon has passed the meridian of a place ?

47. Explain the following :—Littoral Deposits, Gulf Stream Drift, Icefloes, Bore, Race, Cloud Burst.

48. How have lakes been produced ? Name the highest lake, the largest lake, the deepest lake, and the lake containing the greatest percentage of salt in solution.

49. Account for the following statements :—

(*a*) 'All the rivers run into the sea, yet is the sea not full.'

(*b*) The sea would contain but little salt were it not for the fresh-water streams.

(*c*) There would be no snow were it not for the heat of the sun.

50. How can it be shown that the earth rotates on its axis from west

to east? Explain the effect produced by the earth's rotation on moving masses of air and water.

(For the first part of the question refer to Par. 2. The effect of the earth's rotation is to deflect currents of air moving directly northwards or southwards to one side, because different parts of the earth's surface are being carried eastward at different velocities (Par. 3). Thus, a wind in the northern hemisphere blowing towards the equator is continually reaching places that have a greater eastward velocity than those it has left. It thus lags behind, as it were, and passes to the west, or **right,** as it moves towards the equator. Hence the trade winds of the northern hemisphere blow from the north-east. Currents of air or water moving northwards pass into regions of less velocity, and appear to get ahead, as it were, passing thus to the east, or **right.** The anti-trades and the Gulf Stream, therefore, flow from the south-west. A similar explanation will show that in the southern hemisphere the deflection of the currents is to the **left** of the observer looking in the same direction. These facts can be illustrated on a large school globe made to revolve on its axis.)

51. Compare the great continents as to area, extent of sea coast, and direction of mountain chains.

52. Draw a figure showing a section of Asia from north to south. Point out the character of the Tibetan Plateau, and explain why the range of temperature at Verkhoyansk (114°), in Siberia, is so much greater than at Madras (12°).

53. Describe the tablelands of South Africa and those of North America west of the Rocky Mountains.

54. Explain the following :—Steppes, tundras, llanos, selvas, pampas, and oases (*see* Glossary).

55. Mention the chief kinds of rock forming the crust of the earth.

56. Describe the chief phenomena accompanying a volcanic eruption, and say what becomes of the products.

57. Write an account of the mode in which volcanoes are distributed on the surface of the earth.

58. What evidence have we of slow changes in the level of certain lands of the globe? (Refer to Par. 50.)

59. How do rain and frost tend to cause waste or disintegration of rocks?

60. Explain the origin of *stalactites*, *surface springs*, and *artesian wells*.

61. 'Water as a transporting agent acts in a double capacity; it conveys material in invisible chemical solution and in visible mechanical suspension.' Give illustrations of these actions.

(The amount of matter in chemical solution in running water varies with the character of the rocks over which it passes, but it has been estimated at 143 tons per square mile. Taking the area of Great Britain at 90,000 square miles, Mr. Roberts calculates that 12,500,000 tons of material are carried down in solution to the sea every year by British rivers. Probably about twice as much is carried in mechanical suspension.)

62. Explain how it is that in some cases rivers form narrow gorges, and in other cases wide valleys.

63. Name some important **deltas,** and explain why all rivers do not form deltas.

64. How is a **glacier** formed? How can its motion be proved? What becomes of the material it transports to lower levels?

65. Explain the terms **denudation, erosion, disintegration,** and **débris.** What is the general effect of the various denuding agents ?

66. What is the meaning of the term climate ? Enumerate the chief causes that determine the climate of a place.

67. Describe the course of the annual isotherms of 60° F. and 50° F. in the northern hemisphere. Why is the course of these isotherms in the southern hemisphere more regular than those in the northern hemisphere ?

68. What do you understand by ' range of temperature ' ? Why does the range of temperature increase with latitude ? What other causes affect the yearly range ? Draw curves to illustrate your answer.

69. Explain the terms ' continental climate ' and ' insular climate,' and give examples of each.

70. Show how the prevailing winds and the elevation of a country may modify the effect of latitude on the climate.

71. What is the effect of ' a southern aspect ' and the drift from the Gulf Stream on the climate of a district in the South-west of England ?

72. Briefly explain :—

(*a*) Why isothermal lines are not parallel to lines of latitude.
(*b*) Why the thermal equator is north of the geographical equator.
(*c*) Why the January isotherms in England run from north to south, while those for July run almost from west to east.

73. Illustrate from North America the various causes affecting climate.

74. Teneriffe is an island situated in lat. 28° 15′ N. and in long. 16° 40′ W. On the summit of the extinct volcano a south-westerly wind often prevails, while a north-easterly wind blows below.

From the above facts find the distance of Teneriffe from the equator, the character of its climate, and how its local time will differ from that of Greenwich. Account also for the opposite direction of the winds.

(A degree of latitude may be taken to be 69 miles. The wind at the summit of the mountain is the anti-trade wind from tropical regions before it has descended to the sea-level ; the wind at the foot is the regular north-east trade.)

75. Illustrate by reference to Australia, Canada, and the British Isles the effect of mountain ranges on climate, especially on the distribution of the rainfall.

76. How does climate affect the vegetable and animal life of the globe ?

77. Explain how winds and ocean currents can carry off the heat given by the sun to the tropics, and give it out again in temperate zones. (Refer to Pars. 60 and 61.)

78. How do you account for the following :—

(*a*) The sun is vertical twice a year at all places within the tropics.
(*b*) The corresponding seasons of the two hemispheres are separated by an interval of six months.
(*c*) The climate of the southern hemisphere is in general more equable than that of the northern.

(The sea has a much greater capacity for heat than the rocks and soil forming the land. It is neither so readily heated nor cooled. In

the southern hemisphere there is a great preponderance of sea, while the large land surfaces are in the northern hemisphere. Hence the seasons in the southern hemisphere are not so well marked as in the northern hemisphere, though the sun is in perihelion in the southern summer. Refer to pages 18 and 101.)

79. What are the Horizontal Zones of Vegetation? Name the vegetable productions of the Equatorial Zone and of the Arctic Zone.

80. How does elevation affect vegetation? What is peculiar in the flora of Australia?

81. Give examples of plants that have been transplanted by man.

82. Where do the following grow, and what kind of climate does each require:—The sugar cane, cotton, rice, the oil palm, the vine, coffee, ebony, opium, sorghum?

83. Describe the **fauna** and **flora** of a Brazilian forest, or of New Zealand.

84. What animals in the New World correspond to the following in the Old:—**Lion, tiger, camel, ostrich, eagle, wild ox**? What are the great *barriers* to animal migration?

85. What are the objections to the arrangement of animals according to climatic zones? Enumerate the recognised zoological regions.

86. Mention the countries belonging to the Australian zoological region, and enumerate the animals peculiar to this region.

87. What mammals inhabit (1) South America, (2) the sea?

88. Write a short account of each of the following:—A **moraine,** a **cañon,** a **geyser, barrier reef, hoar frost,** and **hail.**

89. Account for—

(*a*) A difference of 47 minutes between the mean time of Paris and Rome.

(*b*) The difference in the length of twilight at places on the same meridian.

(Twilight is due to some of the sun's rays being reflected back to the earth after the sun has set by the dust-motes of the higher layers of the atmosphere. This happens until the sun gets 18° below the horizon. The higher the latitude, the more is the sun's course inclined to the horizon, and the longer is it in reaching the twilight limit below the horizon. Near the equator its course is nearly perpendicular to the horizon, and hence twilight in the tropics is short.)

90. Explain **horizon, meridian, tropic, eclipse.**

91. Mention the chief varieties of mankind, and name the races now inhabiting North America, stating to which great division each belongs, and which are the aboriginal inhabitants of the continent.

92. What races now inhabiting Europe do not belong to the Caucasian branch? Where are the following found:—Hovas, Maoris, Kirghis, Kaffirs, Kelts?

93. Name the distinguishing peculiarities and the branches of the Caucasian or white stock. How is the Aryan branch divided?

94. What is meant by **environment,** and how does it affect the different races of man?

95. How is the progress of mankind influenced by climate?

96. Illustrate the effect of climate and other external conditions on *national character*.

97. How has man affected and influenced animal life and Nature generally?

98. What do you understand by:—Habitat, Coolies, Kanakas, Pygmies, and Races of Mankind?

99. Define the terms:—Day, year, lunar month, calendar month, midsummer, midwinter.

(Midsummer is the date of the summer solstice, June 22, astronomically the beginning of summer. It is so called as summer in England is often considered as beginning in May. Midwinter is the date of the winter solstice, December 22, astronomically the beginning of winter; so called because winter is often considered to begin in November.)

100. How do you explain the phases of the moon?

101. Briefly explain the conditions causing—(*a*) a lunar eclipse, (*b*) a solar eclipse.

---

102. What is meant by the following terms as applied to rivers:—**Source, watershed, divide, affluent, left bank, cataract, bed, levée**?

103. 'River valleys are either wide and shallow with gentle slopes, or narrow and steep-sided.' How do these different kinds arise?

(Where the rainfall is abundant a river valley is the combined result of the deepening action of the river and the widening action of rain and other weathering agents. Where the climate is very dry the deepening action of the river operates without the action of rain on the sides. *See* Par. 54*a* and Glossary, 'Cañon.')

104. Explain the terms:—**Prairie, pot-hole, escarpment, striated block, talus, sand-bar, karroo.**

105. How are the following found:—The mean annual rainfall of a place, the mean annual temperature, the yearly range of temperature? Give instances where the range of temperature is great, and explain the causes.

106. What do you know about **Globigerina Ooze, the Simoom, a Nevé, the Landes,** and a **Summer hill-station** in the Himalayas?

107. State clearly what becomes of the rain that falls upon the ground. (*See* Par. 54.)

108. How has it been proved—

(*a*) That a glacier moves downwards;
(*b*) That air always contains more or less water-vapour;
(*c*) That negroes can work in climates fatal to Europeans?

109. Suppose a large island were situated in the middle of the Atlantic between the parallels of 45° and 55° N., about half as broad as long, and with a mountain chain near most of its west coast, describe the climate you would expect it to have in different parts.

110. What is the direction of the prevailing winds between latitudes 40° and 50° S.? Account for this direction. What is the effect of these winds on the weather of Tasmania and New Zealand?

111. Explain—

(*a*) The reason why mountains are frequently covered with cloud.
(*b*) The cause of land and sea breezes.
(*c*) The effect of 'Wallace's line' on animal migration.

112. Mention—

(*a*) Animals that have been, or are being, exterminated by man.
(*b*) Districts that have been rendered fertile by human agency.
(*c*) Examples of white races displacing native races in a country.

113. In what parts of the world are the following animals found:—*Chimpanzee, opossum, sloth, tapir, camel, zebra, lemur*?

114. Describe any noteworthy features connected with the following :—Khasi Hills, The Great Karroo, Krakatoa, Verkhoyansk, the interior of Australia.

115. To what extent do islands show peculiarities of animal distribution ?

(A consideration of the fauna of islands has led to their division into two groups :—(*a*) **Continental islands,** which have an indigenous fauna of mammalia and amphibia, closely resembling the fauna of the adjacent parts of the continent of which they once formed a part ; and (*b*) **oceanic islands,** which have few or no mammalia, and no amphibia at all, and which never had any connection with a continent. Great Britain and Madagascar may be taken as examples of the first group. The fauna of Great Britain is very similar to that of the Continent of Europe, but poorer. There are no peculiar generic or family types, though there is a peculiar grouse, a few kinds of peculiar fishes, and some peculiar insects, especially moths. Madagascar, from its longer separation from Africa, has a remarkable fauna, no large carnivora like Africa, but many peculiar lemurs; and some peculiar reptiles, especially chameleons. (Some naturalists regard Madagascar as the remnant of a great continent that once existed in the Indian Ocean, to which they give the name **Lemuria.** As examples of oceanic islands we may mention Kerguelen, in latitude 50° S., about half-way between Australia and the Cape of Good Hope. Here there are no mammals, no land birds, except a kind of duck, but many peculiar species of insects. The Galapagos, a group of volcanic oceanic islands 600 miles west of Ecuador, have peculiar huge tortoises, peculiar lizards, birds, and insects. New Zealand, though formed of islands of the continental type, has also a remarkable fauna. It has no marsupials, like Australia, nor, indeed, any mammals, except bats and a kind of rat. Many large flightless birds, as the **moa** or dinornis, have recently become extinct ; while several species of small wingless running-birds, called the apteryx, still exist.)

116. What is meant by ' representative species ' of animals ? Give examples.

117. Briefly explain the terms **Cordillera, Alluvium, Stratum, Plateau, Llanos.**

118. Explain why caverns are common in limestone districts. (*See* Par. 53.)

119. In what parts of the world are the following found :—**Gorilla, reindeer, crocodile, beaver, seal, emu, llama, yak?**

120. Compare (*a*) the climate of an oceanic island with that of a great continent ; (*b*) the aborigines of New Zealand with those of Australia.

121. Set forth, as briefly and clearly as you can—(*a*) Why places on the same parallel of latitude have not the same mean annual temperature ; (*b*) why the river Rhone enters the lake of Geneva as a muddy stream, and leaves it as a clear current. (*See* Pars. 60, 61, and 43.)

122. How do you account for the fact that the amount of rainfall often increases with elevation above the sea-level ? Give figures to illustrate the fact. (*See* Par. 28.)

123. How does proximity to the sea or to a large lake affect the range of temperature of a town ? (Refer to Pars. 60 and 63*a*.)

124. Show how climate affects the character, occupations, and commerce of a people.

125. What causes lead to the aggregation of large populations

in towns? Account for the large population in Glasgow, Belfast, Birmingham, Hamburg, Cairo, Chicago, Calcutta, San Francisco, Johannesburg, Montreal, Berlin. (*See* Par. 72 and Quest. 183.)

126. Find from maps in this book: a rainless, or almost rainless, district of North America; the path of the annual isotherm of 50° F.; places in England that have an average July temperature of 60° F.; the districts of heavy rainfall in Great Britain; the line of volcanoes bordering the Pacific Ocean.

127. Explain the meaning of the terms **contour** and **hachure** with figures. What is meant by **sea-level**?

128. Reproduce some of the symbols used in the One-Inch Ordnance Survey Map. What do V-shaped contours with the lowest contour at the broad end of the V teach you? Design a piece of ground to show a valley with rising ground on the south side and a plain on the north.

129. Draw a section from Helvellyn to Brown Rigg on the map on page 142. What is the average gradient—the rise per 100 feet of horizontal distance—from the lake side?

130. What does a map of the world showing the annual isotherms teach you? How are such isotherms found?

131. How can the shortest distance between two places on a globe be found? What is the shortest distance between New York and San Francisco? *Ans.* 36½° = 2,525 miles.

132. For what purposes is a terrestrial globe useful? Why is it impossible to transfer the network of parallels and meridians accurately to a plane surface?

133. Describe the Stereographic Projection. Where are areas exaggerated upon it?

134. Describe the Globular or Equidistant Projection. For what purposes is it used? Where is it defective?

135. How is the network of parallels and meridians for a map of the world on Mercator's Projection obtained? (*See* Par. 83.)

(The straight line taken to represent the equator is divided into 360 equal parts or into some fraction of 360. Lines drawn through the divisions perpendicular to the equator represent the meridians. This causes the degrees of longitude to remain the same instead of diminishing towards the poles, as on a globe. To keep the degrees of latitude proportional to the degrees of longitude these are increased in size more and more. This keeps the shape of any land or sea represented, but exaggerates its area, the exaggeration increasing as we reach higher latitudes. A degree of longitude at 60° is only half the length of a degree at the equator, and to keep the proportion the degree of latitude is doubled there. The area shown at latitude 60° is thus twice as great as on a globe. At latitude 80° the area shown becomes six times too great. Yet the projection is useful if this exaggeration of area is remembered. The bearings of all points on the map are the true compass bearings, so that the relative positions of two places are easily seen, and it is useful for the sailor who sails by compass. It is also useful for showing the *directions* of isobars, isotherms, winds and ocean currents, though the exaggerated area over which these two last appear to prevail must be borne in mind.)

136. Describe the Conical Projection. For what kind of map is it specially useful?

137. Describe a form of Equal Area Projection. What purposes does it serve? What are its defects?

138. Why cannot the scale on a map of an extensive area be used to measure distances ? (*See* Pars. 78 and 86.)

139. Explain the terms Celestial Sphere, Sensible Horizon, Visible Horizon, Rational Horizon. How does the visible horizon increase with altitude ? (*See* Par. I.)

140. Describe the daily rotation of the stars to an observer at lat. 45° N. Draw a diagram of the celestial sphere at this latitude and put in the diurnal circles of the stars. (*See* end of Par. 91.)

141. How do you find the Pole Star ? What are circumpolar stars ? Give drawings with your answer.

142. How do the stars appear to rotate each day (*a*) to an observer at the pole ; (*b*) to an observer at the equator ?

143. How does the sun's daily path across the sky differ during the year to an observer in London ? Account for these differences.

144. What is the altitude of the midday sun at the equinoxes and solstices to an observer (*a*) at lat. 60° N. ; (*b*) at lat. 42½° S. ; (*c*) at lat. 0°.

145. Why are different constellations (groups of stars) seen at the same hour at different times in the year ? How could you recognise the sun's eastward motion on the celestial sphere ?

146. What are the *climatic zones.* (*See* Glossary.)

147. Describe the *planetary winds.* (*See* Glossary.)

148. What districts have rainy seasons and dry seasons ? Why ? (*See* Glossary.)

149. Besides its daily motion across the sky from east to west, the moon has an eastward motion with reference to the sun and stars. How would you recognise this eastward motion ?

(The eastward motion with respect to the sun is easily seen on observing the distance of the new crescent moon from the sun when it first appears, and the increase of this distance on successive nights —about 13° per day. To recognise its eastward motion with respect to the stars, *see* Par. 94.)

150. On what does the moon's phases depend ? Give an account of its chief phases, with a drawing.

(The moon being a dark body, its phases depend upon its position with respect to the earth and sun. The reader should learn to draw fig. 110 from memory, or any part of it.)

151. Draw figures showing the relative positions of the sun, earth, and moon at the first quarter, at full moon, at new moon, and with a gibbous moon decreasing. Draw the corresponding phases (no attempt need be made to draw the objects and distances to scale).

152. What is meant by the expression, 'the moon's age' ? What is the age of the moon at the last quarter (the third quarter of its orbital revolution), and at what time will it then be seen in the south ?

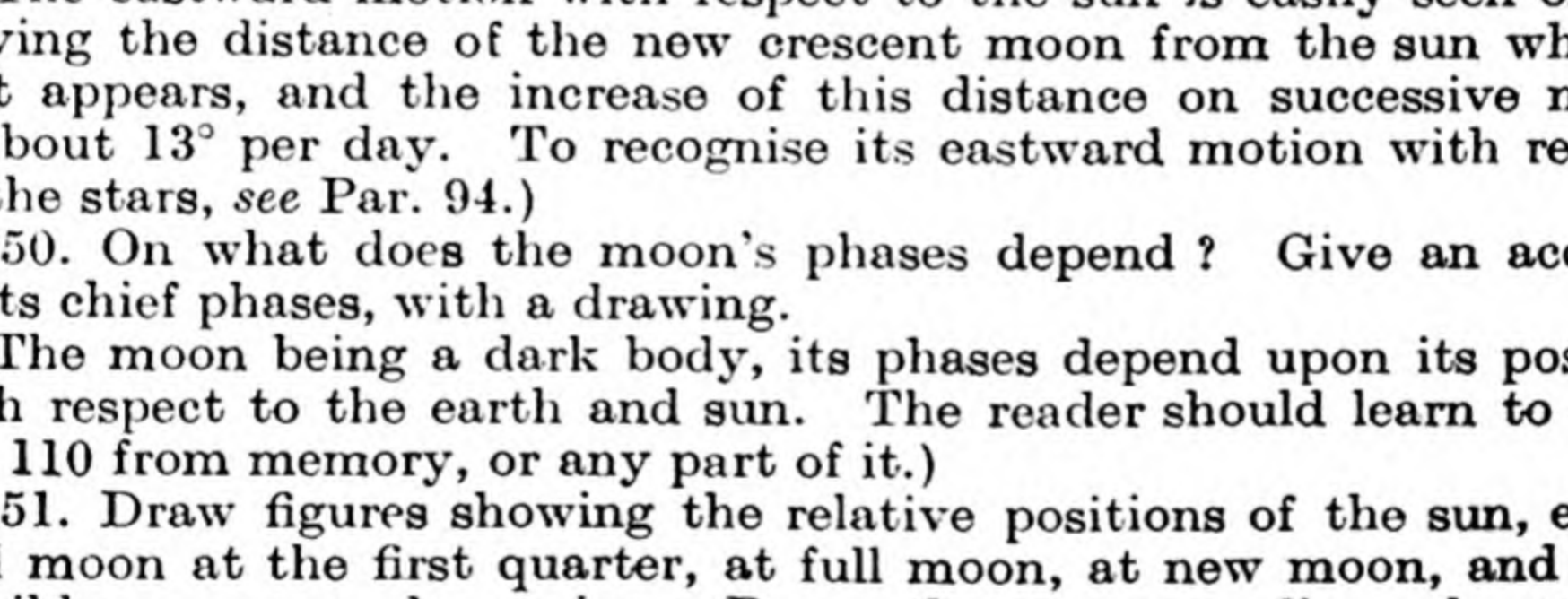


FIG. 145.—FOUR PHASES OF MOON.

153. When the new moon is just visible, when does it rise and set ? When does the old moon crescent rise and set ?

(The new crescent moon rises just after the sun, and sets just after it. The old crescent moon rises just before the sun and sets just before it.)

154. How do you distinguish between (*a*) the waxing crescent of a new moon and the waning crescent of an old moon ; (*b*) between a half-moon a little more than seven days old and a half moon a little more than twenty-one days old ?

(*a*) By the form of the crescent and the position of its illuminated convex side, and by the time of the day at which it is seen ; (*b*) by the position of the convex illuminated side with respect to the west and east, and by the time of the day at which it rises and is seen in the south. (*See* Par. 95 and fig. 145.)

155. Explain how an eclipse of the moon is brought about.

156. When can an eclipse of the sun occur ?

157. Draw a figure to show the apparent path of the sun at the equinoxes and the solstices to an observer at lat. 60°, at lat. 0°, and lat. 90°. What is the sun's zenith distance at these places on these dates ? (*See* figs. 102, 103, 104, and remember that the sun is 23½° N. at the summer solstice, and 23½° S. at the winter solstice.)

158. Explain how the latitude of a place can be found ? (*See* Glossary.)

159. How does a navigator find his longitude ? (*See* Glossary.)

160. In sailing westward round the world, a day appears to be lost on returning home. How is this ? What happens on going round the world eastward ?

(Travelling westward, or towards sunset, causes the sun to set later and to rise later, and the day, as measured from one meridian passage of the sun to another, is more than 24 hours long. The local time of the places reached continually gets later, and the traveller moves the hands of his watch back one hour for every 15° of longitude westward. If he were to start from Greenwich and proceed westward round the earth, in a certain number of rotations of the earth he would see one less than this number of noons, and record one day less ; *i.e.* he would have made N − 1 turns with respect to the sun, while the observer who remained behind had made N turns. Hence, on reaching the place from which he started, he appears to have 'lost a day,' being one day of the month behind, though it is really made up of the hours that he puts his watch back. Similarly, a traveller going round the world eastward finds the local time continually getting faster, puts his watch forward and seems on his return to have 'gained a day.' (*See* Jules Verne's 'Round the World in Eighty Days.') In order to keep the dates right, therefore, mariners going westward add on a day when crossing the meridian 180° from Greenwich, and drop a day when crossing the same meridian going eastward.)

161. Name as many places as you can through which the zero meridian passes, and the place through which meridian 180° E. or W. passes.

(A meridian on the earth may be regarded as a semicircle passing from pole to pole, the opposite semicircle being the opposite meridian 180° from it.) Name also places situated on the Tropic of Cancer and on the Tropic of Capricorn. At what date is the sun vertically overhead to an observer on each tropic ?

162. At a certain place on December 25 the sun attained its

maximum altitude, which was 14°, at 12·5 P.M. Greenwich mean time. The declination of the sun on the day in question was 23½° S. Find the latitude and longitude of the place where the observations were made. (*See* Glossary, 'Latitude and Longitude.') *Ans.* Lat. 52½° N.; long. 1° 15′ W.

163. Explain the following:—Flood-plain, drainage area, divide. Compare the drainage areas of the Atlantic Ocean with those of the Pacific. What Continent has the greatest inland drainage? (*See* Glossary.)

164. Explain meridian, altitude, azimuth, declination, polar distance, great circle sailing.

(Great circle sailing is sailing on the shortest possible route between two places. (*See* Glossary and fig. 93.)

165. Describe the different kinds of valleys, and say how each is produced? What are river terraces?

166. What parts of the world have rainy seasons and dry seasons? Account for the rainy season of India.

167. How can a barometer be used to measure the height of a mountain? (*See* Glossary, 'Barometric Corrections.')

168. What is meant by 'barometric gradient'? How can it be found? What does it teach?

169. Represent by a graphic curve on squared paper the annual rainfall at the following places:—The Stye (lake district), 177 inches; Ben Nevis, 151 inches; Glencoe (Argyleshire), 128 inches; Mangerton (near Killarney), 86 inches; Dublin, 25 inches; London, 24 inches; Brigg (Lincolnshire), 22·5 inches. Account for the cases of heavy and low rainfall?

170. Describe a rain-gauge. How would you use it to find the mean annual rainfall of a place? (*See* fig. 32 and Glossary.)

171. Describe two ways in which you can obtain your north and south line, and the east and west points of the horizon. (*See* Glossary, 'Cardinal Points.') Explain the use of a pocket compass for this purpose, and for finding the 'bearing' of an object.

172. What is meant by the **relative humidity** of the atmosphere? How can it be found? When could you describe the air as moist? What is meant by **dew-point**?

173. Write a short account of three of the following:—A rainbow, an oxbow lake, the pole star, antipodal points, a sundial, a snow crystal, a degree of latitude.

174. How do you account for the following:—The heavy rainfall on the west of New Zealand, the slight rainfall in Egypt, the floating of an iceberg, the descent of a glacier, the talus at the foot of a steep cliff, the filling up of a lake, the shifting of a divide, a waterfall?

175. How are currents caused? How have their directions been found and current-charts compiled?

(Surface currents are caused by prevailing winds (Par. 38), and, like winds, move clockwise in the northern hemisphere, and counter-clockwise in the southern hemisphere. Their direction, which is modified by the earth's rotation (Par. 38), has been ascertained by observation of drifting wrecks and by examination of sealed bottles thrown overboard at the places indicated on the paper sealed up and then picked up later on a beach or by other ships.)

176. How does the position and length of the noonday shadow of an upright object vary at different parts of the year at different latitudes?

(In the zone called 'the tropics' or the *torrid zone*—*i.e.* between the Tropic of Cancer 23½° north, and the Tropic of Capricorn 23½° south—

the noonday shadow of an object is sometimes directly beneath it, sometimes to the north, and sometimes to the south, for the midday sun is in the zenith twice a year, once when moving north of the celestial equator and once when moving south. When the sun is vertical, an upright object will have no shadow, or have its shadow directly beneath it; when the sun is to the south, the shadow of an upright object will be to the north, and when the sun is to the north, the shadow will be to the south. The length of the noonday shadow increases as the altitude of the sun at any place diminishes. Thus, at Kingston, in Jamaica, lat. 18° N., the noonday shadow will be longest and to the north at the winter solstice, December 21; on a day in May, when the sun is vertically overhead, there will be no shadow; after this day the shadow will pass to the south until near the end of July, when the sun will again be vertical.

In the north temperate zone the noonday shadow points exactly north, and the length of the shadow increases as the midday altitude of the sun diminishes, and *vice versâ*, but on any given date the noonday shadow will be longer the greater the distance of a place from the equator. In the southern hemisphere the noonday shadow points exactly south, and has similar variations in length. At any one place in the temperate zones the noonday shadow is longest at the winter solstice of that hemisphere, and diminishes to its minimum at the summer solstice. Within the Arctic and Antarctic circles, when the sun is visible it travels all round the horizon during the day, so that a person's shadow will travel all round and be always opposite to the sun. Its length will depend, as just explained, on latitude and time of the year.)

177. How can you calculate the length of the noonday shadow of a vertical stake two feet high and standing on a level surface in your latitude on June 22?

(On June 22 the sun is at the summer solstice (northern hemisphere), and is therefore $23\frac{1}{2}°$ N. of the celestial equator. As shown near the end of Par. 92, the distance of the sun from the zenith is then equal to the latitude of the place less $23\frac{1}{2}°$. Therefore, for, say, latitude 53°, the distance of the sun from the zenith on June 22 is $53° - 23\frac{1}{2}° = 29\frac{1}{2}°$. Draw A B vertical to represent 2 feet. Draw B C D horizontal. With a protractor make angle B A C = $29\frac{1}{2}°$. Produce B A vertically to Z and C A to S (fig. 146). The sun is shining then along B A C, and its shadow is represented by B C, which can be *measured*. Angle S A Z or B A C gives zenith distance of sun and angle B C A its altitude. [At an equinox zenith distance of sun is equal to the latitude of the observer; at winter solstice the zenith distance is latitude plus $23\frac{1}{2}°$.])

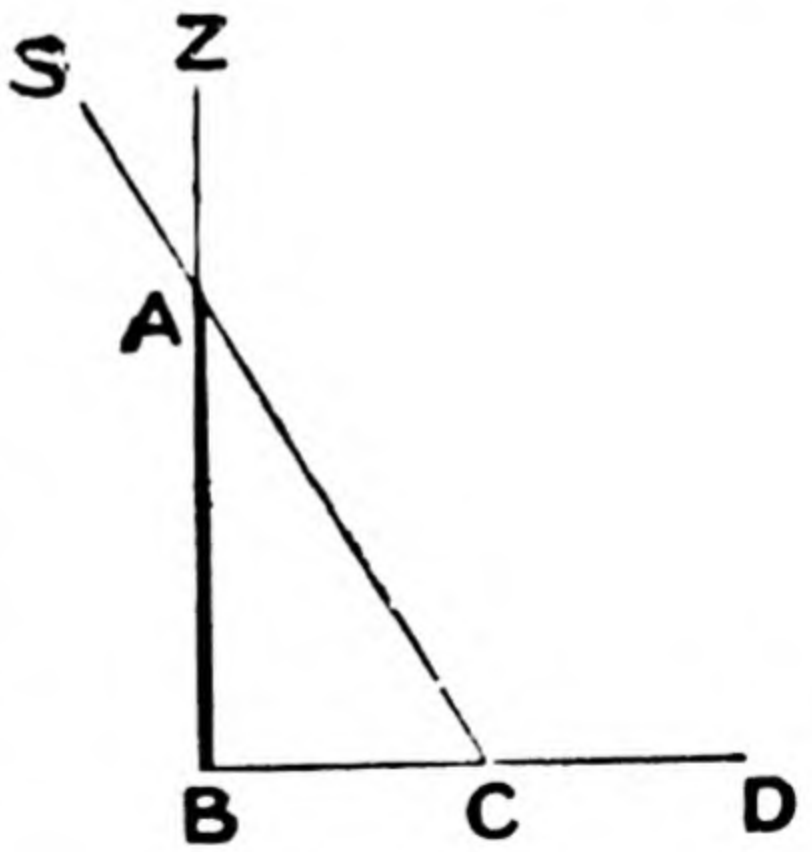


FIG. 146.

178. Given a measuring-tape, squared paper, and a protractor, how could you determine the noonday altitude of the sun at any time?

To find the altitude of the sun at any time from the length of the shadow, measure the length of the upright stake and the length of the

shadow at the time of observation. Mark off on squared paper distances proportional to the length of the upright object and the length of the horizontal shadow. Join the point representing the top of the stake with the point representing the end of the shadow. With the protractor measure the angle thus formed on the paper at the extremity of the shadow. This gives the altitude of the sun at the time of observation, for 90° minus the sun's distance from the zenith gives the sun's altitude, angle B C A in fig. 146.

179. What is a natural region in Geography ? Give examples.

(A natural region, as distinguished from a political region, is an area of the earth's surface where similar physical conditions are found. These similar conditions may include the surface relief or the climate, or both. Other conditions, such as the nature of the soil, may also be brought into account. In Europe, for example, we see from a good physical map (orographical map) that the surface may be divided into distinct regions, (1) a highland or mountain region on the N.W. in Scandinavia, (2) a mountain region running east and west in the centre of the Continent, (3) a Mediterranean region south of the central mountain region, (4) an upland region of plateaux on the northern side of the central region, (5) a great undulating lowland plain stretching continuously from the shores of the English Channel and the North Sea to the east of Europe and in Russia spreading out from the Arctic to the Baltic. This great European plain, however, shows varieties of climate as we pass from the equable climate on its western seaboard to the continental climate of South-East Russia. We may therefore divide this plain into natural regions called *climatic provinces* (*see* Glossary), each climatic province having its consequent vegetation. Thus we have an area of equable climate that includes the North of France and Belgium, an area with a somewhat greater range of temperature in North Germany, an area of the Black Sea with a still wider range of temperature, but remarkable for its fertile black earth and rich wheat production, the steppe land area around the Caspian with a clear type of continental climate, the mid-Russian area and the area of tundras around the White Sea. Two well-marked natural regions of Europe are the plains of Hungary and Lombardy, encircled by the Carpathians and Alps respectively. The former produces wheat and maize, the warmer southern plain olives and rice.

180. A stream flowing along a steep-sided valley in a hilly district is dammed for a reservoir just below a point where several feeders join the main stream. When filled the level of the water in the reservoirs stands at 400 feet O.D. Draw a map of the reservoirs and the district around, using contour-lines.

(O.D. stands for Ordnance datum or O.S. datum, Ordnance Survey datum, *i.e.* mean sea-level. (*See* Par. 74. Map 10 will be found helpful.)

181. Give the names of islands in the tropics and say which will have two rainy seasons and two dry seasons. Account for the seasons.

(*See* Glossary, 'Rainy Seasons.')

182. 'Everywhere the inferior race tends to disappear in presence of the superior and more civilised one.' Discuss this statement.

(*See* last part of Par. 69 and Par. 71.)

183. Account for (1) the large population and industries of Swansea and Zurich, (2) the great cultivation of rubber trees.

(Swansea is a seaport on the border of a large coalfield. Its chief industries are copper smelting and tin-plate manufacture. It is cheaper

to bring copper ore (from Spain) and tin ore (from Singapore) to the coal supply than to take coal to the ore supply. Zurich has an abundant supply of water-power, furnished by falls and rapids, for producing the electric current that drives the machinery of its manufactures (silk, cotton, machines). It is also an important railway and educational centre. Rubber trees are largely cultivated in the Amazon and Congo Basins, in Malay, and the East Indies, as rubber has now numerous industrial uses.)

184. Describe a Synoptic Weather Chart. Point out the relation of the winds to the isobars. (*See* Glossary, 'Weather Charts.') Put in on fig. 119 the probable weather at each part of the cyclonic area.

185. Explain the terms :—**Rain-shadow, Continental Shelf, Mediterranean Climate, Hanging Valleys, Cirques, Date Line.**

The comparative dryness or dry spaces on the leeward side of mountains exposed to moist winds is termed their **rain-shadow** (see fig. 33). The Pennine Range has rain-shadows on the east, the Peruvian Andes on the west, etc.

The shallow sea-bed (up to a depth of 600 feet) bordering the great continents is called the **continental shelf**. It is, except where high mountains border the coast, many miles broad. On continental shelves the coast and river deposits are laid, and on them the great fisheries of the world are carried on. At the border of a continental shelf the depth of the sea rapidly increases.

There is evidence that some continental shelves have been above sea-level, for signs of subsidence are found in the continuance of the river valleys across the shelves, and the shelves join on to a broad coastal plain (fig. 147).

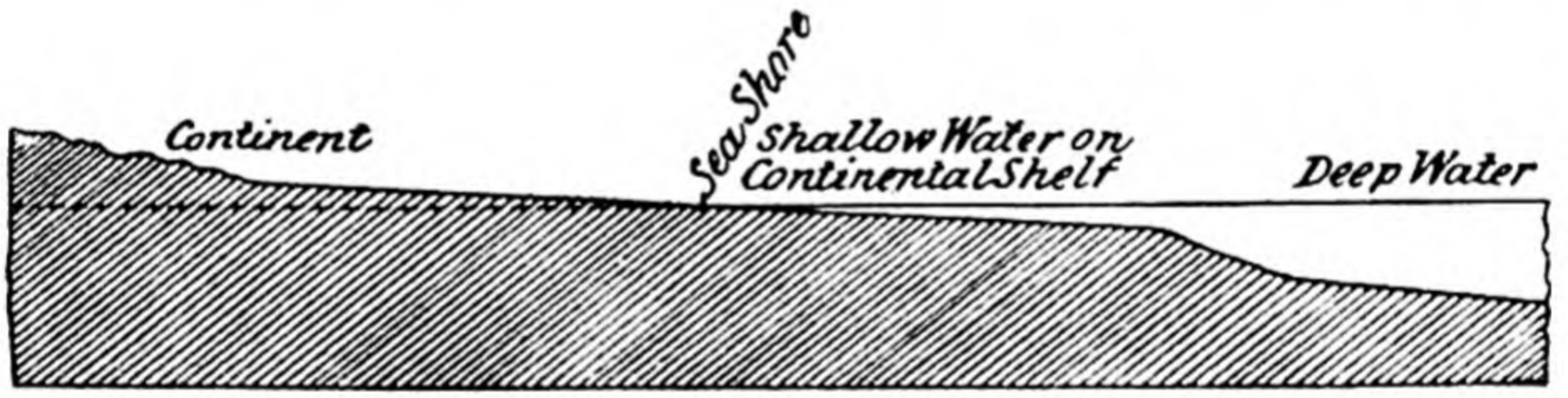


FIG. 147.—DIAGRAMMATIC SECTION SHOWING WIDE COASTAL PLAIN AND BROAD CONTINENTAL SHELF.

The British Isles are on a wide continental shelf that borders N.W. Europe, for the sea-floor does not fall below 100 fathoms (one fathom = six feet) until we get some distance from the western shores of Scotland and Ireland. Newfoundland, too, stands on a continental shelf uniting the island to Labrador. A continental shelf 50 to 100 miles broad borders much of the eastern side of North America. Off the coast of South America the coastal plain and the continental shelf are both narrow.

The **Mediterranean type of climate** is characterised by dryness in summer and rain in winter. It is found in north temperate zones, where the lands are under the influence of the south-west moist winds in winter. In summer, however, the N.E. trade wind belt moves north, so that the countries of the Mediterranean are then brought under the influence of the N.E. trade winds that are blowing from higher to lower latitudes and are therefore dry (Par. 20).

Valleys through which glaciers pass are widened and deepened; for, although clean ice erodes but little, yet a glacier carries pieces of rock in its sides and bottom and has great eroding power. A glacial valley is usually flat-bottomed or U-shaped. The deepening of a valley by a former large glacier or by a large river has often brought about a curious relation between this valley and the smaller side or tributary valleys where the erosion was less. The floor of these side valleys thus lies high above that of the main valley, so that the lower end of the side joins the main valley by a steep drop, over which a smaller stream often drops. Such side valleys lying high above a main valley are called **hanging valleys.** Examples are found in the mountainous districts of Great Britain and other former glaciated regions.

The upper end of many glacial valleys high up on a mountain side terminates in a large, nearly circular valley with steep back and sides called a **corrie** or **cirque**; *i.e.* a cirque is shaped something like an office arm-chair. The floor of a cirque often contains a small lake. Cirques are found high up on the mountain sides at the head of valleys in the Highlands of Scotland, in Wales, in several regions of North America, etc.

The Date Line used by sailors is the meridian 180° E. or W. of Greenwich. It runs from pole to pole through the Central Pacific, passing just east of the Fiji Islands, and in crossing it mariners make a change in the date of the month and the day of the week. The need for making a change of date somewhere is evident when we consider that in westward travel with the sun the days are lengthened as compared with the day at the fixed starting place. Hence going westward round the world a day appears to have been lost, a traveller arriving as he thinks on June 6 when it is really June 7. Going eastward round the world a traveller appears to have gained a day on arriving at his starting point. (*See* Question 160.) It is plain, therefore, that somewhere on the globe when going round it westward a traveller must omit a day and set his calendar a day on; going eastward he must repeat a day and set his calendar a day back. The meridian 180° E. or W. is the line chosen for this change of date in circumnavigation, and is therefore called the **date line.** West of this line (but E. of Greenwich) it is one day later than on the east of it; *i.e.* for example, it was Saturday June 10 on the west side of the date line, when it was still Friday June 9 on the east of the date line. By finding the time on the date line when it is noon at Greenwich the reader will see that any given day may be considered to begin first just on the west side of the date line. (The international date line deviates from meridian 180° between Siberia and Alaska and also for some distance south of the Equator in order that certain islands may have the same day as the adjoining countries.)

186. Show how geographical conditions (latitude, temperature, rainfall, soil, mineral resources, etc.) determine or influence human occupations.

Human occupations are largely controlled by the various elements of climate and mineral supply (Par. 70). The polar zones and rainless deserts do not support life and are without permanent inhabitants. In other zones early man often led a **nomadic** or wandering life dwelling in tents and obtaining a livelihood by **hunting** wild animals or **pasturing** domesticated ones, for a pastoral people must keep moving its flocks and herds in search of fresh pasture. Such nomadic people are still found in many parts. Among **nomads** may be included the Kirghis

of the great grass lands or steppes of S.E. Europe and the district east of the Caspian Sea, the red Indians of N. America, the Eskimo fishers, and the wandering Arabs of Arabia and the Sahara. Nomads are also found on the tundra regions of the north polar zone, these nomads being employed in hunting the fur-bearing animals, and being greatly dependent on the reindeer that can feed on the mosses and lichens that grow on the tundras. (*See* Glossary, 'Tundras.')

In forest regions **lumbering** occupies many men.

Ranching, or the rearing of cattle and sheep, is the occupation of a great number in the great *grass lands* (*see* Question 187). The cultivation of the cereals is the more settled life of large numbers in the fertile river valleys and plains where there is a proper supply of rain. Many dry areas have however been converted into fruitful land by **irrigation,** water being stored up in times of plenty and then distributed in dry periods by canals and other channels. Such areas are found in Egypt, in parts of India, in Australia in connection with the river Murray, etc.

Mining is a great settled industry, coal and iron mining being the most important. Many examples of a large population engaged in these industries may be found in the British Isles, the continent of Europe and the United States of America. Such mineral wealth accounts for the great population of the counties of Durham and Glamorgan compared with the population of Cambridge and Merioneth. (*See* Par. 72.)

Under the term **manufactures** is included a large number of employments, in most of which extensive use is made of machinery. A cheap supply of coal is one of the main factors, as steam power is required to drive the machinery, so that all coal-field areas tend to become great manufacturing centres. Striking examples of this are to be found in Great Britain, in parts of Europe, and in parts of North America. The history of **Water Power** in industries is noteworthy. In the early days of the industries of Lancashire and Yorkshire, for example, water power obtained from water-wheels was the chief source of power, so that the factories were on the banks of streams on the slopes of the Pennines. When coal was introduced as fuel to provide steam power, the factories were built on or near the coal fields, and water power fell into disuse as it was not so economical as coal. Recently, however, with the advance of science water power has again become important since it can be transformed into electrical energy, and this is easily transmitted to convenient centres. Hence the manufacturing industries of Switzerland (cotton, silk, engines, machinery, etc.) have increased greatly during the last 25 years, a vast amount of machinery being now driven by electricity produced by the numerous waterfalls and rapid streams. Many other countries also make use of their water power to provide electric energy. All manufacturing areas occupy many people in the **transport** of the manufactured goods and of the food required by the workers.

187. Give a short account of—(*a*) the forests of the temperate regions of the earth, (*b*) the great grass lands of the globe.

The forests of the temperate regions are found where there is a fairly regular supply of rain, as trees need such a supply. They include the warm temperate forests of evergreen trees, the cool temperate zone of trees that shed their leaves in winter, **deciduous** trees, and the sub-arctic zones of coniferous trees with needle-shaped leaves (Pars. 65, 66).

Grass lands are areas of the temperate zone where the rainfall owing to the dry summer will not support the growth of trees. There are

many varieties of wild grasses and it is these areas where pasture grass is the prevailing growth that are called **grass lands.** Such grass lands are the steppe lands of S.E. Russia and the adjoining parts of Asia, the prairies of N. America between the Appalachians and the Rockies, the Pampas of Argentina, and the Downlands of Australia. Some grass lands are found in the Torrid Zone where the summer is long and dry—the Llanos, of the basin of the Orinoco and the Park lands of S. Africa between the Zambesi and the Kalahari desert. Much natural forest land in Canada and other countries has been cleared for grass land. The rearing of cattle and sheep on these great grass lands employs many graziers or ranchers. The cattle are mainly reared for their beef and the sheep for their mutton and wool, the meat being now sent out in vast quantities in vessels possessing freezing chambers. Ranching has been pushed back in Canada, Argentina and other parts by ploughing up the grass land and growing wheat, maize and other cereals for export. How one occupation leads to and is dependent on another is seen when we notice how the beef, mutton and cheese of the rancher as well as the arable farmer's wheat and maize of these districts lead to the construction of railways to bring these products to ports on the sea-coast, to the growth of great ports from which the food stuffs are shipped, *e.g.* Buenos Aires, and to the building of steam-ships for conveying the goods to the dense population of Great Britain and Western Europe.

188. Upon what do the following depend—(*a*) density of population in a country, (*b*) the establishment of harbours, (*c*) the cultivation of rice, (*d*) the cultivation of the vine ?

Density of population depends on several factors, such as temperature, fertility of the soil, mineral wealth, especially coal and iron, and favourable situation for commerce. Great river valleys having a good rainfall, as the valley plains of the Ganges and Hoang-ho, support a dense population ; while deserts, tundras and high mountain slopes are sparsely populated. For the other factors refer to the causes producing the great centres of population in Europe and America. (*See* Par. 72.)

A good harbour is best formed up a deep estuary where the hinterland is productive, easily accessible, and thickly populated, *e.g.* Liverpool on the Mersey, Hamburg on the Elbe, Buenos Aires on the River Plate.

For the cultivation of rice and the vine, *see* Table in Par. 67.

189. What are the data required to construct an isothermal map showing July temperatures ?

Distinguish between isotherms and isothermal surfaces, isobars and isobaric surfaces.

An **isotherm** is a line joining places that have the same average temperature at sea-level for a certain period (day, month or year). (*See* Pars. 17, 18.)

Average or mean temperature is found by taking the sum of a number of suitable readings of the thermometer during the period and dividing by the number of readings. Readings at 7 A.M., 2 P.M., and 9 P.M. divided by 3 will give, when corrected to sea-level if need be, the average **daily** temperature. The mean temperature for any month (say July) is the average of all the mean daily temperatures during that month, and the average of the mean temperature of this month for a number of years gives us the general mean temperature for that month. When such mean temperatures are found for a suitable number of places in a district, the isotherms of this district can be

drawn on a map of that region. In this way we get isothermal maps or charts, such as Maps 1, 2, 11, 12.

The air temperature at a place falls as a rule as we ascend. (Par. 17.)

An **isothermal surface** is a **surface** in the atmosphere upon which the temperature is everywhere the same. Over a plain on which the sun is shining and the air still, the isothermal surfaces (say of 50°, 52°, etc.) will be horizontal surfaces at certain heights in the air. On the side of a hill rising from the place on which the sun is shining the air in contact with the mountain becomes warmer than the air at the same level on the plain. In such cases the isothermal surfaces would slope upwards on the mountain side.

An **isobar** is a **line** joining places that have the same air pressure as shown by the barometric readings (corrected for temperature and reduced to sea level) at the same period. (*See* Par. 16.)

An **isobaric surface** is a **surface** in the atmosphere on which there is the same atmospheric pressure. Such a surface will meet the sea level along the line of an isobar, *e.g.* the isobaric surface of 29·7 inches along the line of the isobar of 29·7 inches. Isobaric surfaces are seldom horizontal for a great distance. In regions of high pressure they will be convex above, in regions of low pressure concave.

(It is noteworthy that the fall of temperature with increase of altitude (often called the *vertical distribution of temperature*) is fairly regular up to a height of about 7 miles. Above this is a thick layer of the atmosphere where the fall of temperature with increase of altitude ceases.)

190. Briefly relate what you know of (*a*) rias, (*b*) fiords, (*c*) natural boundaries.

Various signs indicate that certain coast-lines have undergone elevation or depression in recent geological times. (*See* Par. 50.)

Rias are bays or inlets of the sea formed by a subsidence of a river valley near a coast where mountain ranges meet the sea almost perpendicular to the shore, *i.e.* rias are a form of **drowned river valleys.** The bottom deepens regularly on passing seawards. Bantry Bay and other bays near it on the S.W. of Ireland are rias. Other coasts with rias are S.W. Wales with Milford Haven, and N.E. Spain, where the bay of Vigo is a good example of a ria.

Fiords are long, narrow branching sea-locks with steep walls, and are due to the subsidence of glacier valleys, the subsidence often also connecting former lakes with the sea. Often there is a shallow bar near the mouth probably due to a terminal moraine (fig. 130), and there is no uniform increase of depth in passing seawards. Hence fiords may be described as drowned glacier valleys. Fiords are found on the Norway coast, the Pacific coast of Canada, and the coast of Greenland. They afford good anchorage for ships, but give rise to no important seaports as the hinterland is mountainous and unproductive.

When subsidence takes place where there are lowland valleys, they give rise to wide **estuaries** as on the east of Scotland. On deep estuaries good harbours arise, as the hinterland is easily accessible and usually thickly peopled. London, Hamburg, and Buenos Aires are examples.

Natural boundaries to countries are such as the sea, mountain ranges, and rivers. A sea-frontier is a definite boundary, and serves as a protection from invasion and an inducement for seafaring.

Mountain ranges are valuable frontiers, as they offer serious obstacles to an invading foe, especially where the passes are few or difficult,

e.g. the Pyrenees, the Andes. One drawback is the difficulty of fixing the crest of the range that is to serve as the boundary.

A river has the merit of providing a definite boundary if agreed upon, but, except it is very wide, it is only a small military obstacle, as military engineers are now able to construct and destroy river-bridges rapidly. Besides, in modern times the tendency is for one country to occupy the further banks of a river for some distance, *e.g.* Germany on both sides of the Rhine, Roumania on both sides of the Danube.

What may be called **mathematical** boundaries are often employed, parallels of latitude and meridians of longitude. Thus from the great lakes the 49th parallel of latitude is the boundary between U.S.A. and Canada, and several states are bounded entirely by meridians and parallels.

191. How would you find on a clear night the latitude of the place where you live? A captain at sea makes observations on June 21 when it is noon with him and finds the altitude of the sun to be 68°, while his chronometer shows 3.10 P.M. Greenwich time.

What is his latitude and longitude?

See Par. 90 and Glossary, 'Latitude,' 'Longitude.'

On finding the angular elevation of the pole star above the horizon I should obtain the latitude at the place of observation.

The zenith distance of the sun is 90° — 68° = 22°. The sun's declination, or distance from the equator on the date mentioned, is 23½°, for the sun on that date is vertically overhead at the Tropic of Cancer (Pars. 6, 92). Now the sun's zenith distance plus the sun's declination when north of the equator gives the latitude, *i.e.* 22° + 23½° = 45° 30′ N. latitude. Because the captain's noon is 190 minutes later than noon at Greenwich, and each four minutes of time gives a difference of 1° of longitude, we have 190 + 4 = 47° 30′ W. longitude.

192. Draw diagrams to illustrate (*a*) winter in the southern hemisphere, (*b*) the altitude of the noonday sun at latitude 45° N on December 21, (*c*) the belt-like arrangement of the chief winds of the globe, (*d*) lateral and terminal moraines.

See figs. 12, 107, 27, 130.

193. In what direction does the noonday shadow of a person (or other upright object) point in the different climatic zones during the year?

During the course of a year the sun appears to move from the Tropic of Cancer, 23½° N., to the Tropic of Capricorn, 23½° S., and then back again, thus crossing the equator twice (*see* Par. 92). Between the two tropics—that is, in the zone called 'the Tropics,' or the Torrid Zone—the inhabitants have, except on the two days when the sun is vertically overhead, the sun sometimes to the south of them at noon and sometimes to the north. Hence in the Torrid Zone noonday shadows fall for some part of the year to the north and for some part of the year to the south.

Between the Arctic Circle, 66½° N., and the Tropic of Cancer is a belt of the earth 43° wide called the North Temperate Zone, where the sun is never vertically overhead, and, as the sun always culminates in the south, the noonday shadow in the North Temperate Zone points due north. Within the Arctic Circle—that is, in the North Frigid Zone—the noonday shadow of the sun also points north. It is worthy of note that in this area there is at least one day on which the sun never sets (the number of days increasing from one on the border to 182 at the

poles), so that on such days the sun travels all round the horizon, and a person's shadow will pass during the day all round, being always opposite the sun.

In the South Temperate Zone the sun reaches its highest point at noon in the *north*, so that here the noonday shadow points due *south*. So also in the South Frigid Zone, where in the winter of the southern hemisphere there is at least one day on which the sun never sets.

194. What is meant by the sun 'crossing the equator' twice a year? (*See* Par. 92 and fig. 106.)

195. (*a*) In what parts of the world may the sun be seen directly overhead about the middle of January? (*b*) The sun shines throughout the day for five days in each year on the north side of a house. What is approximately the latitude of the house?

(*a*) On December 22nd the sun is vertically overhead at the Tropic of Capricorn, 23½° S., after which it turns northward towards the equator. About the middle of January, therefore, it would be vertically overhead at noon about 17° S.; (*b*) In all places north of the equator during the northern summer the sun rises to the north of due east and sets to the north of due west, and we need therefore only consider the position of the noonday sun. At a place on the Tropic of Cancer 23½° N. the sun is vertically overhead at noon on June 22, so that on that day the rays of the sun will reach the north side of a house directly throughout the time the sun is above the horizon. At a place a little south of 23½° N. the sun will shine on the north side of a house throughout the day for four or five days in succession. Hence latitude required is a little south of the Tropic of Cancer. (*See* Pars. 6, 92.)

196. What is the midday altitude of the sun at a place 53° N. latitude (*a*) at the spring equinox; (*b*) at the summer solstice; (*c*) at the winter equinox? An examination of a figure of the celestial sphere at any latitude will show that the meridian or midday altitude of the celestial equator is 180° − (90° + the given latitude). (*See* fig. 104.) Hence at lat. 53° N. the meridian altitude of the celestial equator is 180° − (90° + 53°) = 37°. At the summer solstice the sun is 23½° above the celestial equator, so that its midday altitude will be 37 + 23½ = 60½°, and its zenith distance will be 90 − 60½ = 29½°. At the winter solstice the sun is 23½° below the celestial equator, so that its midday altitude at the given place will then be 37 − 23½ = 13½°. Its variation of altitude at any other latitude can be determined in a similar way. At all places outside the tropics there is a difference of 47° between the altitude of the midday sun at midsummer and the midday sun at midwinter.

197. A stake is set upright out of doors on level ground. You are provided also with a measuring tape, squared paper, and a protractor. How would you use these materials to find the altitude of the sun? Draw a diagram showing the stake and the lengths of the shadows which it casts (1) at noon on June 21, (2) at noon on September 21, (3) at noon on December 21.

Place the stake upright on a horizontal surface. With the tape measure the length of the upright stake and the length of the shadow at the time of observation. Then mark off on the squared paper distances proportional to the lengths of the upright stake and the length of the horizontal shadow. Join the point representing the top of the stake with the point representing the end of the shadow. With the protractor measure the angle thus formed on the paper at the extremity of the shadow. This gives the altitude of the sun at the time of

observation (*see* fig. 20), where angles A*wb*, A*eb* and A*sb* give the altitudes of the noonday sun at the winter solstice, at the equinoxes and at the summer solstice.

198. How is the air heated ? Why does the temperature of the air diminish with increase of altitude ?

The temperature of the air at any place—the shade temperature—is found by means of a thermometer placed in it and protected from the direct rays of the sun. With the exception of a little heat from the internal heat of the earth, the air is heated partly by the direct rays of the sun that pass through it and are absorbed by it, and partly indirectly by the sun's rays that reach the earth. The amount of the sun's rays absorbed directly by the air varies according to the thickness of the atmosphere, according to the density of the air passed through, and according to the amount of water vapour, water particles and dust particles in the air. The sun's rays that reach the ground and water of the earth are absorbed. The warmed earth warms the air in contact with it, and also radiates heat back into the lower layers of air where it is absorbed by the water vapour and dust particles in these lower layers. (*See* Par. 17.)

The temperature of the air diminishes with altitude, because the higher we go the rarer becomes the air, that is, there is less of it in a given space ; less of the sun's direct rays are absorbed by this rare air ; the rarer air is drier and farther removed from the radiation of the earth.

199. Why does the mean air temperature decrease as we pass from the equator to the poles ?

The sun's heating effect on the air and earth is greatest when its rays fall most vertically, because each unit of area exposed to vertical rays receives a larger proportion of these rays than it does of slanting rays and less heat is absorbed by the various layers of air when the sun's rays fall obliquely than when the rays fall vertically. (*See* fig. 16 and Par. 59.)

200. What is meant by daily and annual '*range of temperature*' ? Why have inland tablelands not only a lower mean temperature than places at the sea level in the same latitude but also a greater range of temperature ?

Daily range of temperature is the difference between the hottest and coldest part of the day ; annual range of temperature is the difference between the hottest month of the year (July in the Northern Hemisphere), and the coldest month of the year (January). Both daily and annual range increase as a rule with latitude and with distance from the sea. (Pars. 59, 60.) The rarer air of tablelands permits the ground of highlands to become hotter when exposed to the sun (at night or in winter), than does the denser air over lowlands ; while, on the other hand, when not exposed to the sun (at night or in winter), the same air allows radiation to go on more rapidly from the high ground than from the ground near sea-level. Hence plateaux and tablelands have great diurnal and seasonal variations in temperature. Thus Madrid, situated on the central plateau of Spain, 2,150 feet high, has a Jmean anuary temperature of about 40° and a mean July temperature of 76°, or a range of 36°, while the range at Lisbon is only about 20°. (*See* fig. 63.)

On the range of temperature in *deserts* see Glossary, 'Desert.'

201. Why is the annual range of temperature of the surface of the sea less than that of the land in the corresponding latitude ?

How does this smaller annual range affect climate ?

Water acquires heat slowly and it requires more heat than an equal mass of any other substance to raise its temperature through any given range; on the other hand it cools slowly, and in cooling through any number of degrees it gives out more heat than any other substance. As a consequence of the above the surface water of the sea shows a less range of temperature than the adjoining land.

The influence therefore of large masses of water is to raise the temperature of the adjoining land at night and during the winter, while during the day and in summer such masses of water tend to cool the air over the land near. Hence seas have a modifying influence on climate by preventing extremes of temperature on neighbouring land. (Pars. 34, 60.)

202. At a place in the Northern Hemisphere the sun was observed on December 21 to reach its greatest altitude above the horizon, $18\frac{1}{2}°$, at 10.56 A.M. Greenwich time. Calculate the latitude and longitude of this place.

December 21 is the date of the winter solstice of the Northern Hemisphere, and the summer solstice of the Southern Hemisphere. On this date the noonday sun is vertically overhead, or reaches an altitude of 90° at the tropic of Capricorn, $23\frac{1}{2}°$ south of the equator. A place having on the same date a maximum altitude of $18\frac{1}{2}°$ will be $90° - 18\frac{1}{2}° = 71\frac{1}{2}°$ from the tropic of Capricorn, but only $71\frac{1}{2}° - 23\frac{1}{2}° = 48°$ from the equator; that is the latitude of the place of observation is 48° N. (In a similar way the latitude of any place at one of the equinoxes or solstice can be found if the highest altitude of the sun on the given date is stated; or from the latitude the highest altitude can be found. (Par. 92.)) The longitude required is 16° E. (Par. 3, Question 3).

INDEX

The Student should also consult the Glossary.

ACTION OF SEA ON ROCKS, 56
Air (*see* Atmosphere)
Alluvium, 80
Alpine climate, 101
Altitude, 175
American Indians, 124, 129
Animals, distribution of, 97, 103, 104, 107, 117
Antarctic Circle, 16
— Ocean, 54, 56
Antarctica, 65
Anti-cyclones, 38
Antipodal points, 176
Antipodes, 176
Anti-trade winds, 36, 176
Apparent daily motion of sun, 165
— motion of stars, 157–165
— — — sun, 157–8, 165
— yearly revolution of sun, 168
Aqueous rocks, 70, 177
Arctic Circle, 16, 18
— Fauna, 118
— Ocean, 49, 52, 54, 55
Arête, 188
Argon, 25
Artesian well, 77
Aryans, 124
Aspect, 94
Atlantic Ocean, 47, 50, 58
— — currents of, 58
Atmosphere, 25–33
— action of, on rocks, 75
— composition of, 25
— height of, 27
— pressure of, 27–8, 33
— temperature of, 29–33, 86, 92
Atolls, 71, 128
Axis of earth, 11
— inclination of, 14–16, 24
— parallelism of, 14–15
Azimuth, 175–6

BANANA, 97, 105, 112
Bar, 82
Barley, 115
Barometer, 28, 177
Barometric corrections, 177
— gradient, 33, 178
— pressure, 28
Barrier reefs, 71
Base-level (*see* Graded Rivers)
Belt of calms, 34
Blizzard, 180
Bore, 64, 180
Boulder clay, 84
Boundaries, 239
Bush Veld, 104

CALMS OF CANCER, 35
— of Capricorn, 35
Cañons, 78, 180
Carbonic acid, 25, 26, 76
Cardinal points, 23, 181
Catchment basin, 78, 179
Caucasian type of mankind, 121, 124
Caves, 76
Celestial meridian, 159
— sphere, 157
Cereals, 110
Chalk, 71
Charts, 132
Chinook winds, 40
Chocolate, 116
Circle, great and small, 11, 145, 148
Circumpolar stars, 160, 164
Cirques, 236
Climate, 85–101
— effect of altitude on, 92, 112
— influence on man, 125
— — on vegetable and animal life, 96
— oceanic, insular, continental, 89–90
— of British Isles, 91, 94
— of North America, 96
— types of, 97–101
Climatic zones, 97 *seq.*, 183
Clouds, varieties of, 41
Coal, 71
Cocoa, 103, 116
Coconut, 103
Coffee, 116
Cold deserts, 112
— wall, 59, 183
Condiments, 117
Coniferous forests, 101, 110, 111, 237
Constellations, 162, 170
Continental climate, 100
— shelf, 235
Continents, 65
Contour, 67–8, 132, 183
Coral islands, 71, 128, 184
Corrie, 236
Cotton, 116
Crater, 72
Crevasses, 83
Currents, 58–61, 232
— influence on climate, 91
Cyclones, 38, 184

DATE LINE, 231, 236
Day, 10, 24
— varying length of, 14
Daylight, duration of, 18
Deciduous forests, 105, 109–10, 115, 237
Declination, 165, 167, 185
Deltas, 80, 186, 192
Denudation, 75, 84
Depressions, 38
Desert, 99, 106–7, 112, 186
— climate, 99, 187
Dew and dew-point, 40, 187
Diatom ooze, 54
Disintegration, 75
Divide, 187
Doldrums, 34, 188
Dolphin ridge, 50
Downlands of Australia, 111, 238
Drainage areas, 188
Drumlins, 84
Dugong, 120
Dunes, 76

Dust of atmosphere, 26–27, 41
Dyke, 70, 189
Dynamical cooling, 44

EARTH, CRUST OF, 69
— exact shape of, 24
— revolution of, 13–14, 24
— rotation of, 10, 24, 35, 58
— size and shape of, 8–10
— zones of, 12
Earthquakes, 74
Ebony, 102, 117
Eclipse, 174, 189
Ecliptic, 14, 24, 167, 190
— plane of, 14, 15
Elevation, 74, 92
Ellipse, 13
Environment, 125, 126–7
Equal area projection, 155, 156
Equator, 11, 190
Equatorial climate, 98
— forests, 102–3
Equinox, autumnal, 15, 17, 22, 166
— vernal, 15, 17, 22, 166
Erosion, 75
Erratic blocks, 84
Escarpment, 191
Eskers, 84
Esparto grass, 117
Estuary, 5
Evaporation, 26, 40

FAUNA, 117
Ferrel's law, 191
Fiords, 191, 239
Firn, 82
Fixed stars, 170
Flax, 116
Flood plains, 191
Flora, 101
Fog, 41
Foraminifera, 53, 71
Forests, 102–4, 105, 109, 111, 237
Fossil, 70
Fresh-water lakes, 64
Fringing reefs, 71, 184
Frost, 76

GEYSERS, 78, 192
Glaciers, 82
Globes, 145–7
Globigerina ooze, 53
Gnomon, 22
Graded rivers, 193
Gradient, barometric, 33, 178
Grasslands, 104, 110–11, 237
Gravitation, 9, 61, 193
Great Basin, 69
— Bear, 162
— circle sailing, 147, 193
Gulf Stream, 58, 91

HABITAT, 102
Hachures, 132
Hail, 47
Halfa, 117
Hanging valleys, 236
Harbours, 238
Hemispheres, 49
Hoar-frost, 41
Horizon, 8, 23, 159, 194 : different kinds of, 159
Horse latitudes, 194
Humidity, 194
Humus acids, 76 *n.*
Hurricanes, 38
Hygrometer, 26, 195

ICE, 54
Iceberg, 55, 82, 83
Ice-field, 54
Ice-floe, 55
Ice-foot, 54
Igneous rocks, 70
Indian corn, 114
— Ocean, 49, 59
Irrigated areas, 113
Island fauna, 228
Isobar, 29 ; maps, 144
Isobaric surfaces, 239
Isotherm, 33, 86, 95, 238 ; maps, 144
Isothermal maps, 144, 238
— surfaces, 239

JUTE, 116

KARROO, 69, 196
Khamsin, 40
Khasi Hills, 46
Kuro-Siwo, 59, 91, 96, 196

LAKES, 64, 69
Land and sea breezes, 37
— hemisphere, 49
Land utilisation maps, 139, 143
Landes, 195
Landslip, 197
Latitude, 11, 12, 145
— effect on climate, 86 ; determination of, 197
Lava, 72
Levées, 80
Limestone caverns, 76
Linseed, 116
Llanos, 68, 198, 238
Longitude, 12, 25, 145 ; determination of, 198

MAGNETIC MERIDIAN, 200
Mahogany, 102, 117
Maize, 114
Mammals, distribution of, 119
Man, influence of climate on, 103, 125
— influence on nature, 127
— types and races of, 121
Mankind, classification of, 121
Map projections, 149–156
Maps, 67, 130 ; scale of, 67, 131, 156 ; sections of, 134, 143 ; various kinds of, 131–2, 148
Marine deposits, 50, 52
Mathematical boundaries, 240
Mediterranean climate, 35, 99, 107–9, 235
— fruits, 107, 116
— Sea, 47, 64
Mercator's projection, 152, 194, 229
Meridians, 12, 22, 145, 199
Metamorphic rocks, 70
Millets, 115
Mineral springs, 77
Mist, 41
Mongolic variety of mankind, 123
Monsoon, 22, 36
— climate, 98–9, 106
— lands, 104–6
Month, different kinds of, 171
Moon, 170 ; influence of, on tides, 61–4

Moon, phases of, 171; eclipse of, 174 190
Moraines, 83, 201
Moulin, 83
Mountain chains, direction of, 67, 93
— — influence on climate, 43–4, 94
Muds, 52, 53

NATIONAL CHARACTER, 126
Natural boundaries, 239
— regions, 234
Neap tides, 63
Negro variety of man, 121
Nevé, 82
Night, 10, 24
— varying length of, 14
Nitrogen, 25–6
Nomads, 236
Noonday shadow, 23, 232–3, 240–1

OASES, 68, 107
Oats, 115
Oblate spheroid, 10, 24
Occupations, 127, 236
Ocean depths, 50–1, 65 *n.*
Oceans, 47
Olive oil, 116
Oozes, 53
Opium, 117
Orbit of the earth, 13, 14
Ordnance Survey Maps, 136, 139
Ores, 70
Organic rocks, 70
Ox bow, 202
Oxygen, 25–6
Ozone, 26

PACIFIC OCEAN, 48, 50, 59
— — currents, of, 59
Pack ice, 55
Paddy, 113
Pamir, 69
Pampas, 68, 202
Pelagic deposits, 52–3
Phases of Moon, 171, 230–1
Physical Geography, 7
Plains, 68
Planetary winds, 203
Planets, 14, 170
Plants, distribution of, 97, 101
— vertical zones of, 112
Plateau, 68, 93, 203
Polar distance, 165
— Front hypothesis, 38
Pole star, 160, 162–3, 203
— — altitude of, 160, 240
Poles, 11
Population, density of, 129–30, 238
— of the world, 125
Pot-holes, 78, 203
Prairies, 68, 204
Precipitation, 204
Projection of maps, 149–156
Projections, 148–56
Pteropods, 53

RACE, 64
Radiolarian ooze, 53
Rain, 42
— action of, on rocks, 76
Rainbow, 204
Rainfall, 42–6, 93, 94–6, 204
Raingauge, 42, 43, 204
Rainless regions, 46
Rain shadow, 235
Rainy seasons, 205
Raised beaches, 74
Ranching, 237
Reefs, 71
Regelation, 83, 206
Relief, 67, 131, 206
Reptiles, 120
Revolution of earth, 13–14, 24
Rias, 239
Rice, 113
Rift Valley, 212
River basin, 178
— terraces, 80
Rivers, 76, 78
Roaring Forties, 36
Roches moutonnées, 84
Rocks, 69–71
Roof of the World, 69
Rotation of earth, 10, 24, 35
Rubber, 102, 116, 235
Rye, 115

SALT LAKES, 64
Salts in river-water, 50, 65, 80
— in sea-water, 49, 65
Sandbanks, 81
Sargasso Sea, 59
Savana, 104
Scale of maps, 67, 131, 156
Sea deposits, 52
— depth of, 50
— effect on climate, 89
— floor of, 50
— level, 132 *n.*, 207
— temperature of, 52
Seas, 47
Sea-water, 49
Seasons, 16, 20–22, 24
— rainy and dry, 22
Section of maps, 134 143
Selvas, 68, 102, 207
Shoals, 81
Sierras, 68
Silica, 70
Simoom, 38, 40
Sirocco, 40
Site of large towns, 129
Sleet, 47
Slope of ground, 94
Snow, 42, 47
Snow-line, 47
Solano, 40
Solar day, 24
— system, 13, 208
Solstice, 17, 166
Southern Ocean, 49
Sphere, 209
Spices, 117
Spring tides, 63
Springs, 76
Stalactite, 76, 210
Stalagmite, 76, 210
Stars, daily motion of, 160–4
Steppes, 68, 110, 210
Stratified rocks, 70
Stratosphere, 27
Striæ, 84
Submerged forests, 74
Subsidence, 74
Sugar, 115
Sun, altitude of, 18, 20, 166
— and the tides, 63
— inclination of rays of, 18, 30
— light and heat of, 18, 20
— motion of, on celestial sphere, 167–70
— shadow of, 22, 240
— zenith distance of, 20, 168
Sundial, 210
Symbols of ordnance, maps, 131, 137
Synoptic weather chart, 215

TABLELAND, 68
Tea, 116
Teak, 105, 117
Temperature, annual range of, 88, 96
— mean, 30; annual, 88
— of the air, 29–33, 86, 92
Terrestrial gravitation, 9
Terrigenous deposits, 52–53
Thermal equator, 34
— springs, 77
Tides, 61–4
Timber, 102, 105, 110, 111, 117
Tornado, 38
Towns, site of, 129–30, 234
Trade winds, 34–6
Tropic of Cancer, 13, 16, 168
Tropic of Capricorn, 13, 16, 168
Tropics, 13
Tropopause, 27
Troposphere, 27
Tundras, 68, 112, 212
Twilight, 18, 212, 226
Typhoon, 38

UNSTRATIFIED ROCKS, 70

VALLEYS, 78, 212
Vegetable products, 113
Vegetation belts, 102
Vine, 97, 107, 116
Volcanoes, 71

WALLACE'S LINE, 118, 120
Waterfalls, 213
Water Hemisphere, 49
Water-parting, 78
Water power, 237
Watershed, 78
Waterspout, 38
Water-vapour, 26, 40–1
Waves, 56
Weather, 85
— charts, 215
Weather diagrams, 217
Weathering of rocks, 76
Wedges of high pressure, 38
Whale, 120
Wheat, 110, 114
Wheatlands, 115
Winds, 33–40
— influence on climate, 91
— local, 40
— variable, 37
Wine (*see* Vine)
Wood pulp, 117

YEAR, LENGTH OF, 13, 24

ZENITH DISTANCE OF SUN, 20, 168
Zodiac, 170; signs of, 170
Zone of calms, 34
Zones, 12
— of vegetation, 112
Zoological regions, 118–120